SANEA
Thinking Energy

BRICS Business Council

ENERGY SKILLS ROADMAP

SOUTH AFRICA

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Wits Business School
Sculpting global leaders

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

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EXECUTIVE SUMMARY

Background and objectives

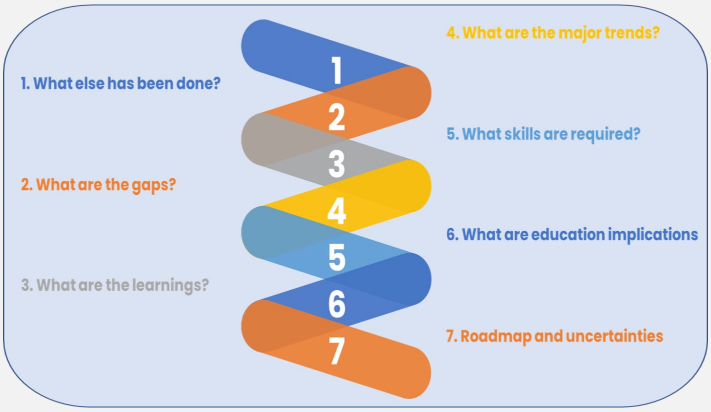
The South African National Energy Association (SANEA) in partnership with the Wits Business School's African Energy Leadership Centre (AELC), the University of Witwatersrand's Centre for Researching Education and Labour (REAL) and with the support of the South African BRICS Business Council proposed the development of a South African Energy Skills Roadmap to support a Just Energy Transition in South Africa. The project is funded by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

It was acknowledged that there are many existing initiatives completed or underway that address skills in the energy sector, however there are gaps in that there is not one cohesive initiative, the broader energy sector is not fully covered, and the longer-term skills are not adequately considered.

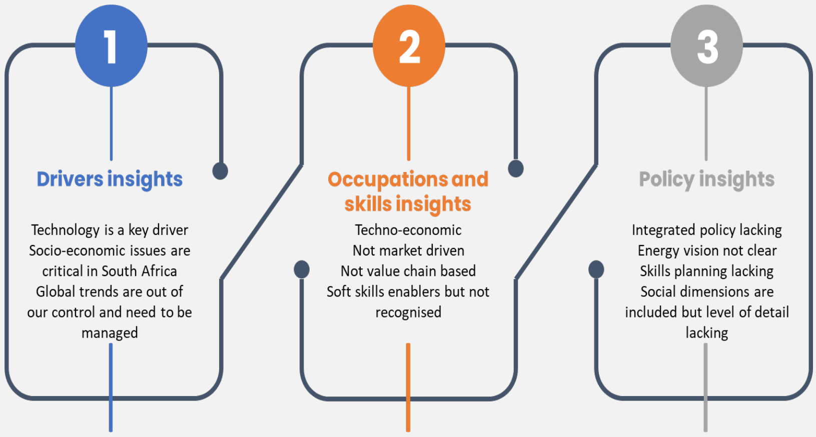
The primary objective of the project was therefore to develop a comprehensive energy and related skills roadmap, identifying new skills and competencies that will be needed in the energy sector in the future because of the energy transition.

Process followed

The project was executed over three phases to answer key questions in the development of a roadmap. The methodology used was a combination of various approaches customised to suit the South African context and energy sector. The detailed process followed is shown in the fish diagram below which culminated in the energy skills roadmap.



Baseline study



This assessment was carried out in Phase 1 of the project and involved identifying and analysing over 200 documents on skills in the South African energy sector over the last 5 years. This avoided duplication; built on existing findings; identified gaps and informed the development of a long-term roadmap of future energy skills.

The work was categorised into four groupings namely Decarbonisation; Decentralisation; Digitalisation and Market structure.

It was concluded that the energy sector is being driven by a number of key trends both global and local. These have critical implications for skills development as not only will current jobs be impacted, but new occupations and skills will be needed.

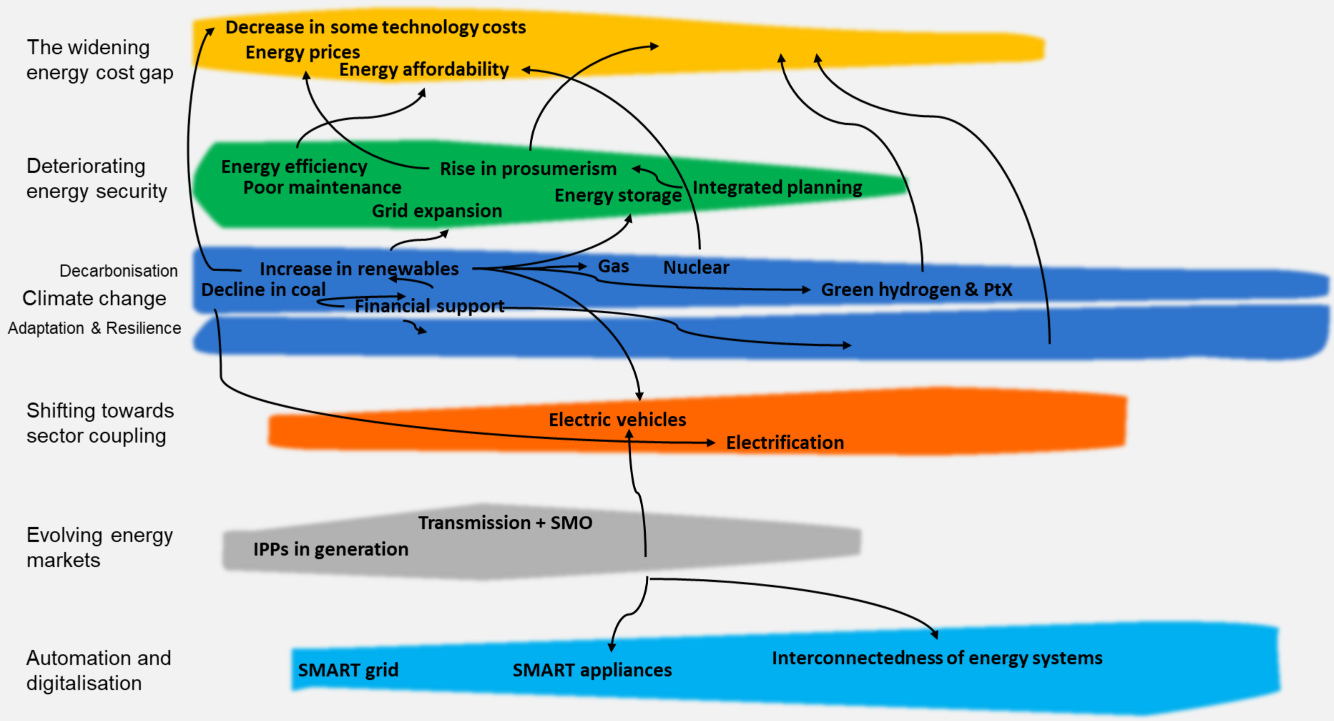
Skills requirements for the energy system necessitates an ecosystem and integrated approach and acknowledgement the transformative process that is occurring over time and local geographic areas. Siloed approaches need to therefore be avoided to maximise any opportunities and build any trade-offs into decision making.

Trends and uncertainty

To determine the future skills requirements, it is critical to predict what future trends will impact on the sector, as well as how various energy players will react to them. This was done at the global level as well as the national level.

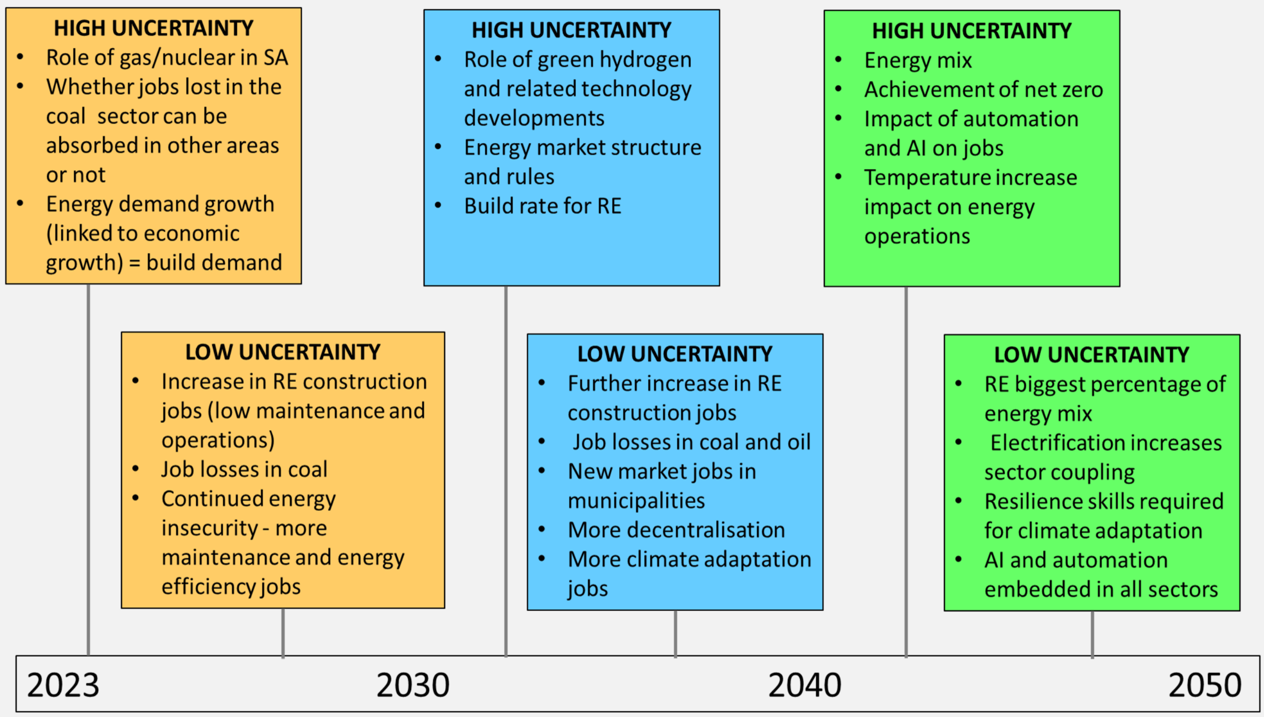
Global Meta trends transforming the world were identified in phase 1 of the project as well as from the political, economic, social, technical, legal and environmental dimension analysis undertaken by SANEA in the development of the *South African Energy Risk Report*, (2022) which also considers global impacts.

A series of workshops held with industry players identified critical trends up until 2050. These trends were consolidated into clusters and prioritised. The additional global trends of automation (including robotics) and Artificial Intelligence (AI) were also identified as being impactful on the energy sector although not necessarily direct energy technologies. These trends are detailed below as well as how they change in terms of rate of change over the time period up until 2050.



It is clear that the energy sector in South Africa is in crisis and faces a great deal of uncertainty in developing a skills roadmap as a result. To deal with the uncertainties, a set of scenarios was developed, and a set of no-regret actions identified. The scenarios and trends were used to identify uncertainties as they could play out over time and impact skills demand and provisioning.

By analysing the trends as well as uncertainties in the energy sector as identified by SANEA in their South African Energy Risk Report, uncertainties that will impact skills supply and demand were identified.



Occupations and skills

The impact of these trends on occupations and skills was analysed per trend and a comprehensive analysis of the various occupations that will be needed over time was carried out. The following emerged:

- The shift to decarbonisation and electrification is being reflected in the increased demand for a wider variety of jobs, including outside the energy sector.
- This has resulted in the emphasis on only techno-economic jobs shifting to include a socio-economic and just transition emphasis as well.
- The private sector is employing specialists in future areas such as green hydrogen to inform policy and clients that will shape the trajectory. The public sector tends to be more focused on current jobs and issues.
- The decentralisation and automation/AI trends are resulting in a shift in the types and locations of jobs from more technical to more construction jobs.
- The emerging energy markets are driving new types of jobs and where they are located geographically and sectorally, e.g. from a central utility to a municipality etc.
- Consideration needs to be given to transversal skills that can be used across various national initiatives such as infrastructure development.

Implications for the education sector

To ensure that the labour market's demand and supply were met, the implications of the energy trends on the education sector were also examined. This included the consolidation of all the current energy-related degrees, diplomas, short courses etc. currently offered in South Africa.

The following conclusions were drawn:

- There is an adequate supply of traditional energy qualifications at the university level (number of qualifications not the number of graduates).
- Traditional energy education is not adequately supplying specialisations such as qualifications in renewables or clean energy.
- It is unclear if post-school curricula and education quality are responding adequately or appropriately to future demand.
- Community and Technical Vocational Education and Training (TVET) colleges are not responding to nor providing appropriate training for current and future local demand e.g., solar in the Northern Cape.
- The skills pipeline from basic education is poor. This is having an impact on the throughput of students in the relevant courses at the tertiary education level.

Skills planning

Skills planning is a critical issue given the integrated and systemic nature of the sector. If adequate and timely skills planning for the energy sector is to be realized, attention should be given to the following:

- The need for flexibility given the uncertainties. This is currently not adequately considered.
- Acknowledge occupation demand and skills along the transition time continuum, not just current and end goals.
- Consider the ecosystem of activity, this being the broader energy sector value chain and geographical location.
- Include skills planning upfront in sector and development plans - not 'tagged on' at the end.
- A single accountable entity for skill planning is required that would include government, industry, academia and civil society (at all levels) to avoid duplication and ensure that the enabling jobs are adequately provisioned.

Considerations and recommendations

Considering all the data, analysis and conclusions, of the following recommendations are made to facilitate implementation, a critical consideration in the South African context.

Consideration	Recommendation
Uncertainty and trends	• Develop a more detailed set of scenarios and impacts on jobs to acknowledge the nuances of each scenario on jobs and locations e.g. Northern Cape etc. • Track uncertainties to feed into flexibility of the skills planning.
Multi-dimensional approach to skills development	The South African skills roadmap will need to have a coherent vision and concurrently work on the following: • Reskilling and upskilling adults to be better equipped to navigate the energy transition at various points in the energy value chain. • Aligning the energy skills development system with the anticipated labour force needs of the future, with a particular focus on jobs to support a just energy transition. This involves sophisticated anticipatory skills development and working with labour market intelligence, as well as the strengthening of skills system innovations across the energy value chain and its associated ecosystem i.e. not to be relegated to a narrow band of technical skills only. It also involves investing in a skills development capacity and building new types of skills and specialisms. • Resourcing foundational skills development throughout the education system to improve the adaptive capacity of the broader workforce. This involves curriculum transformation, teacher capacity development in the schooling and post-schooling system (especially also TVET and community educator competencies), restructuring employer-provider (demand-supply) relations, and expansion and diversification of learning pathways (currently the skills for green jobs arena is dominated by high-skills learning pathways). • The skills plan will need to offer national-level strategic support and local-level alignment with emerging priorities and opportunities. Mediating between national to local is critical as the roadmap unfolds. The focus should be on capacitating governments and national entities but also consider bottom-up skills processes that could be driven and/or informed by local affected communities.

Consideration	Recommendation
Occupation and skills	● Development of an occupation and skills atlas. ● Undertake an employee workplace-based survey to develop clearer ideas on workplace-based learning needs. ● Undertake skills ecosystem mapping in high-impact areas (either decrease or increase in jobs). ● 'Soft' skills need to be identified and accommodated across various job levels. ● Consideration needs to be given to transversal occupations and skills that can be used across various national initiatives such as sector and infrastructure development plans.
Implications for the education sector	● To investigate energy transition-related student throughput (graduations) vs employer demand. ● Curriculum review of energy transition-related course content for relevance / specialisms (especially within critical hotspot geographical areas). ● Understanding learning pathways in the energy sector through a focused and detailed study of how job seekers can progress within the energy sector. This should include the streams of work associated with core jobs that are going to be impacted by or required to transition South Africa's energy sector. ● To review or research to better understand how to enhance partnerships to provide education and training.
Skills planning	● The skills implementation plan should be driven by one accountable entity, yet include government, industry, academia and civil society (at all levels) to avoid duplication, that enables jobs to be adequately provisioned, and is responsive to ever-changing uncertainties. ● Cross-SETA collaboration and coordination to support skills provisioning for the energy transition. ● Develop and implement an energy just transition skills implementation plan and a skills hub that can coordinate skills planning processes (governance, time, cost, research).

ABBREVIATIONS

AELC	Wits Business School's African Energy Leadership Centre
AI	Artificial Intelligence
BRICS	Brazil, Russia, India, China, South Africa
DHET	Department of Higher Education and Training
DMRE	Department of Minerals Resources and Energy
EWSETA	Energy and Water Sector Education and Training Authority
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
ICT	Information and Communications Technology
IEA	International Energy Agency
ILO	International Labour Organisation
IPPs	Independent Power Producers
IRENA	International Renewable Energy Agency
IRP	Integrated Resource Plan
OFO	Organising Framework for Occupations
PCC	Presidential Climate Commission
PESTLE	Political, economic, social, technical, legal and environmental
PtX	Power-to-X products
PSET	Post-school Education and Training
PV	Photovoltaics
RE	Renewable Energy
REAL	University of Witwatersrand's Centre for Researching Education and Labour
REIPPP	Renewable Independent Power Producer Programme
SADC	Southern African Development Community
SANEA	South African National Energy Association
SMART	Specific, measurable, achievable, relevant, and time-bound
TVET	Technical Vocational Education and Training
UN	United Nations
Wits	University of the Witwatersrand

INTRODUCTION

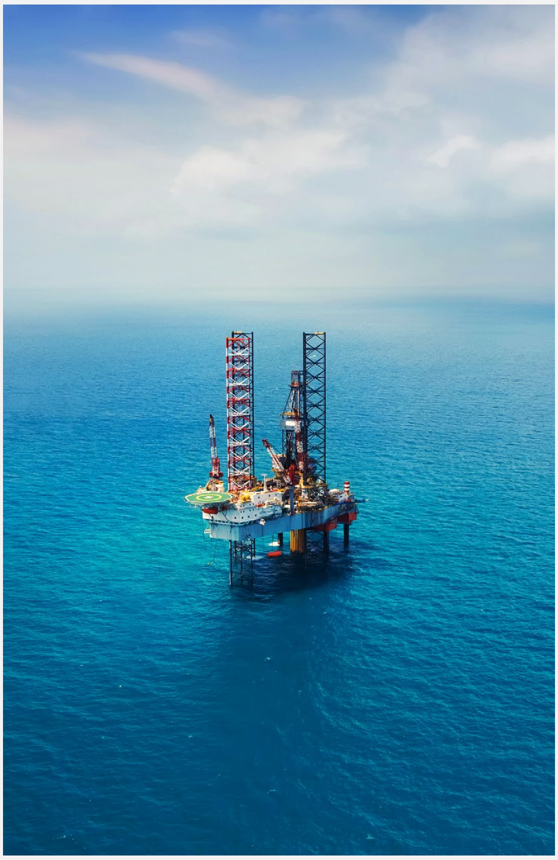
Overview of the South African energy sector

South Africa is located on the southern tip of Africa and has one of the largest economies on the continent. Table 1 provides an overview of South Africa's current and future energy transition landscape (Climate Investment Funds 2020, Stats SA 2022a, and TIPS, 2022)

Table 1: Summary of South Africa's current and future energy landscape

Population	60.6 million (2022)[4]	Total electricity production	239,459 million KWh (2020)[1]
GDP	US$ 62,94 billion (2022)[5]	Primary energy supply	Coal (65%), crude oil (18%), renewables and waste (11%), gas (3%), nuclear (2%) and geothermal (1%)[9]
Unemployment rate	35% (2022b)[7]	Electricity market	Industrial sector (51%), transport (26%), commerce & public sector (11%), residential (7%), and agriculture (2%)[9]
Employed in the energy sector	59,000 (2021) [electricity][8]	% of population with access to electricity	85% (2019)[1,2] [Urban, 88%; Rural, 79%][2]
Main economic sectors	Mining, transport, energy, manufacturing, tourism and agriculture[6]	Future energy mix	43% coal and 34% wind and solar by 2030[10]

Purpose and Objectives of the Roadmap



The South African National Energy Association (SANEA) in partnership with the Wits Business School's African Energy Leadership Centre (AELC), the University of the Witwatersrand's Centre for Researching Education and Labour (REAL) and with the support of the South African BRICS Business Council proposed the development of a South African Energy Skills Roadmap to support a Just Energy Transition in South Africa. The project is funded by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

It is acknowledged that there are many existing initiatives completed or underway that address skills in the energy sector, however there are gaps in that there is not one cohesive initiative, the broader energy sector is not fully covered, and the longer-term skills are not adequately considered.

The primary objective of the project is therefore to develop a comprehensive energy and related skills roadmap, identifying new skills and competencies that will be needed in the energy sector in the future as a result of the energy transition.

The project also aims to identify strategies to ensure that the right skills are in place when they are needed, as well as the identification of those skills that will no longer be needed or will be needed at much lower levels in the future because of the energy transition, and the development of strategies that will reorient and reskill.

This work is in support of the *Just Energy Transition Frameworks* as developed by the Department of Minerals Resources and Energy (DMRE) as well as the Presidential Climate Commission (PCC). Both have stated that skills are essential and need to be assessed.

METHODOLOGY

What informed the approach?

The approach was informed by defining the scope of the work which covers South Africa over a period up until 2050 and encompasses the electricity and related and/or supporting sectors. This approach was taken in order to ensure that the ecosystem required to support the Just Energy Transition was recognised and skilled appropriately to provide an enabling environment. The value chain illustration of the scope is detailed in the figure below:

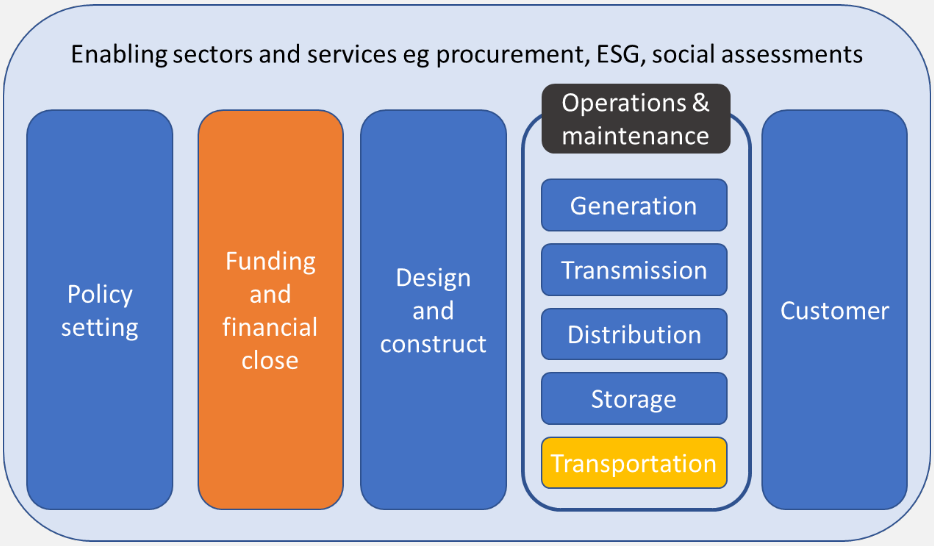


Figure 1: Value chain illustration of the scope of the skills roadmap

Overall approach and questions to be answered

The project was executed over three phases to answer key questions in the development of a roadmap. The methodology used was a combination of various approaches and customised to suit the South African context and energy sector. The detailed process followed is shown in the fish diagram below which culminated in the energy skills roadmap.

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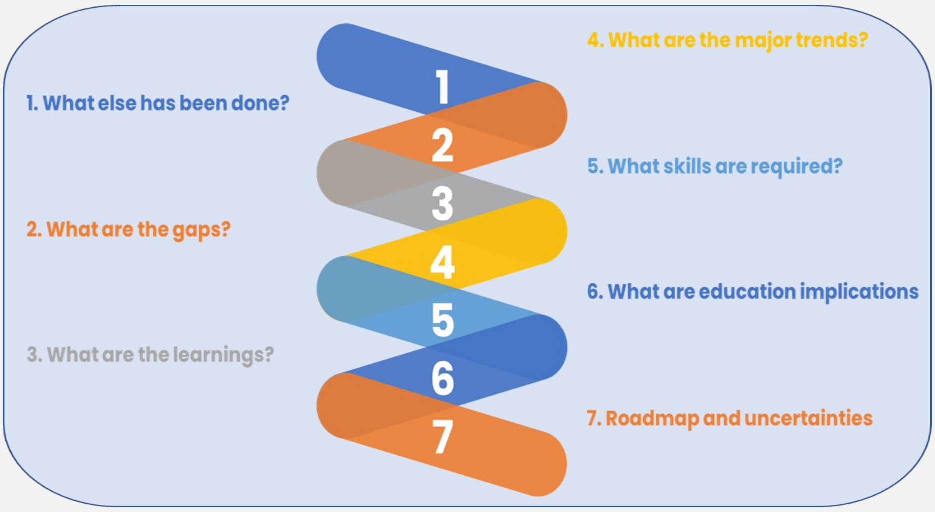


Figure 2: Questions to be answered

Detailed phases of the project

The project has been executed in three phases namely:

Phase 1: Set up and define a detailed scope of work. In this phase the scope was to:

The intent was to include as many people working in the area as possible, to ensure the work was adding value and not a duplication of effort SANEA

- Set up a database of projects related to this initiative.
- Conduct interviews and get stakeholder input into the scope and objectives and confirm the gaps.
- Set up an Advisory Committee of active stakeholders working in this area.
- Develop a baseline dataset of current skills categories and training facilities.
- Develop a list of experts and interested and affected parties.

Phase 2: Developing the energy skills roadmap. In this phase the scope was to:

- Hold a series of workshops with representatives from government, labour, affected communities and business to validate the baseline data from Phase 1.
- Hold three workshops with interested and affected parties to develop the baseline data for emerging jobs in the energy sector in South Africa.
- The first two workshops to identify trends utilising the database of projects and analysis thereof.
- The third and fourth workshops on skills identification and implications for the education system. Input data from an analysis of job adverts over the last year in South Africa that related to the energy sector and information on the current energy sector education system through an analysis on providers.
- Hold a final workshop to develop a set of recommendations for business, government etc as well as to identify additional work.
- Analyse to link trends to ways of work plus implications for jobs and skills and skills provisioning as well as emerging themes.
- Hold a final validation workshop.
- Write a report and publish.
- Set up a virtual 'Impact Community.'

Phase 3: Communication and dissemination of results. In this phase the aim is to widely disseminate the report through seminars, publications and targeted events.

The overall process across three phases is detailed in the figure below:

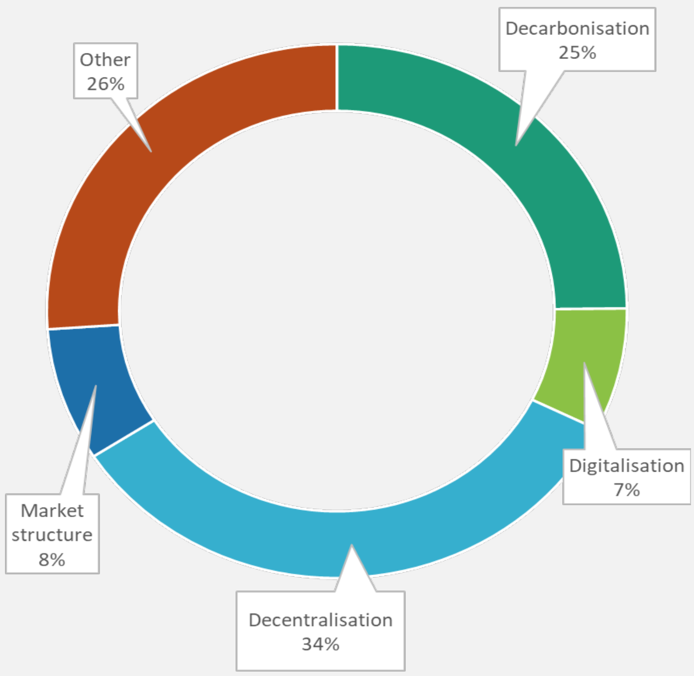
Figure 3: Detailed process followed in the development of the energy skills roadmap

BASELINE ASSESSMENT

This assessment was done in Phase 1 of the project and involved identifying and analysing over 200 pieces of work done on skills in the energy sector over the last five years. This was done to avoid duplication, build on existing findings, identify gaps, and to inform the development of a long-term roadmap of future energy skills for South Africa.

The work conducted was categorised into the following major themes: Decarbonisation, decentralisation, digitalisation and market structure.

The analysis found the following:



The data gathered in this phase of the work represents the collation of a significant body on work done in South Africa on energy skills. The Energy and Water SETA have provided a repository where this data, as well as any future work can be stored in one place and shared with researchers and other interested and affected parties. [ENERGY SKILLS ROADMAP - Energy & Water SETA (ewseta.org.za)]

Figure 4: Distribution of data sources across the 4 themes

The literature gathered was analysed for the following:

- What occupations, skills (hard and soft) and knowledge had been identified (see section on skills demand for results)?
- Policy issues and recommendations.
- Technology issues and choices (see section on meta trends below for results).

The policy issues across the report were analysed to identify what policy was mentioned the most often, as a gauge of importance. This result is detailed below:

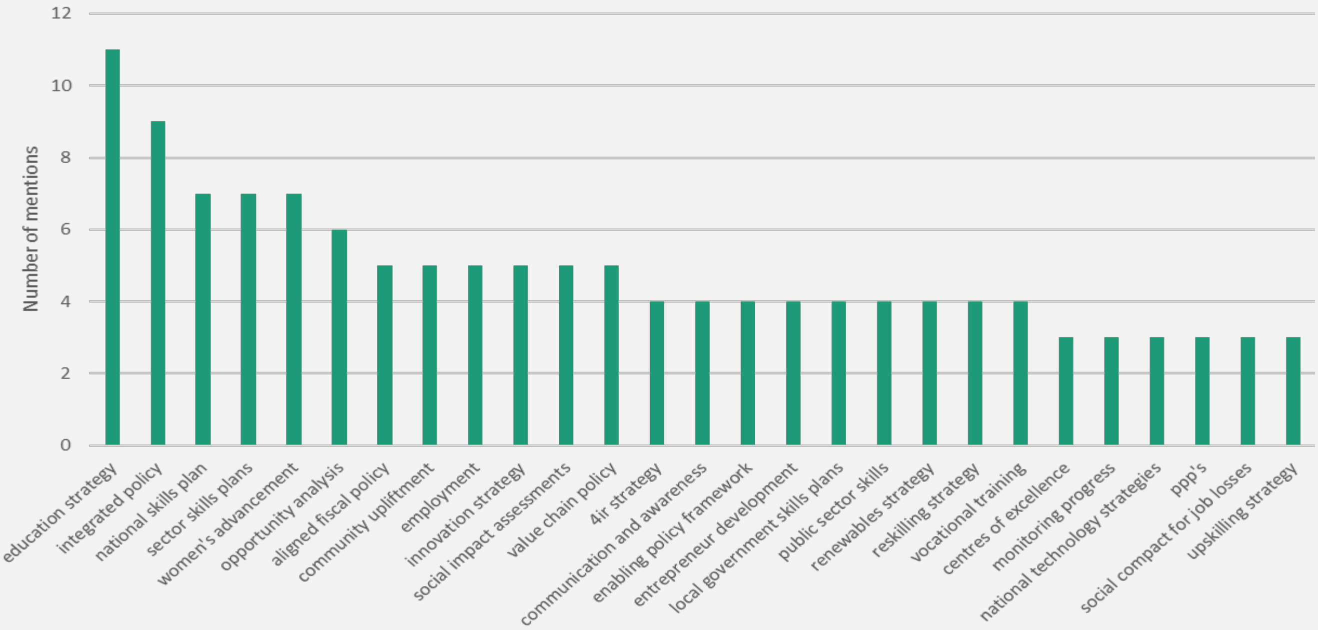


Figure 5:	Number of mentions of policy across the relevant publications

The outcome of this analysis is detailed below and it was concluded that:

- No common vision of the future and therefore the transition steps required are either not adequately dealt with or are fragmented.
    - This is due to the fact that many of the studies are based on single technologies and not an integrated picture or even along specific value chains.
    - Data on current numbers and types of jobs is not available.
    - Projections are oftentimes not grounded in hard data or extrapolated from a single technology or project base.
- Skills studies are often technology not market or opportunity driven.
- Skills studies do not consider the skills required in the new system e.g. municipalities now having to deal with new technologies and markets.
- Occupations are techno-economic centric and too generic (e.g. not classified at occupation level as per the Department of Higher Education and Training's (DHET) Organising Framework for Occupations (OFO).
- Some skills are cross-cutting and transversal across different occupations e.g. Information and Communications Technology (ICT).

- Skills requirements are too generic and have not been devolved to the lowest level – which affects those most severely impacted by the transitioning of the sector e.g. technicians.
- 'Soft' skills are key enablers but do not receive attention e.g. leadership and critical thinking, and skills required for integrated policy formulation.
- Regional differences are not always considered e.g. specific skills requirements in Mpumalanga where the mining workforce will be affected by mine closures.
- Sector coupling implications (positive and negative) are not always considered.

This is graphically represented in the figure below:

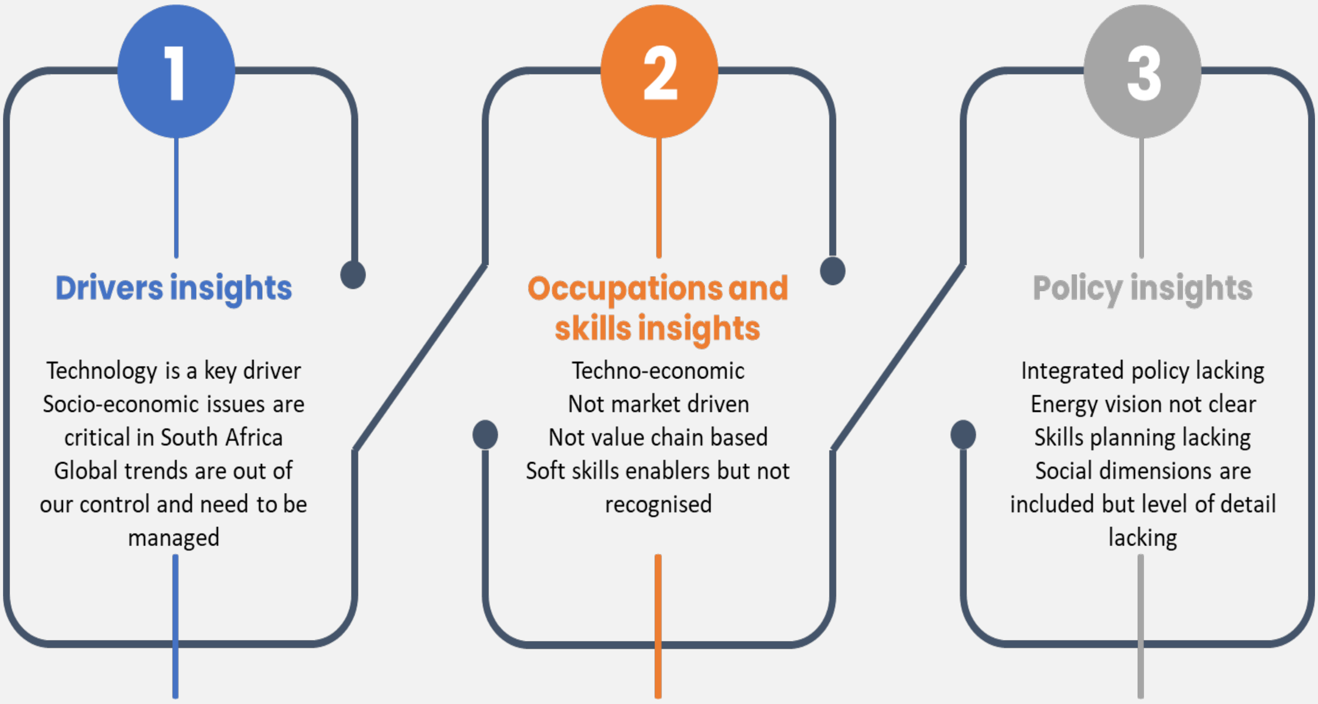


Figure 6: Outcomes of the data analysis from Phase 1

SOUTH AFRICAN ENERGY SYSTEM TRENDS

Introduction and purpose

To determine the future skills requirements, it is critical to predict what future trends that will impact on the sector are, as well as how various energy players will react to them. This was done at the global level as well as the national level

Global meta-trends

Global Meta trends transforming the world were identified from phase 1 of the project as well as from the political, economic, social, technical, legal and environmental (PESTLE) dimension analysis undertaken by SANEA in the development of the South African Energy Risk Report, which also considers global and national impacts (MacColl, 2022, EWSETA, 2022, SANEA 2022. WEF 2022,). .

This analysis also drew on the energy experts group which is utilised as part of the SANEA Energy Risk Report process.

The figure below illustrates these trends as they pertain to the energy sector.

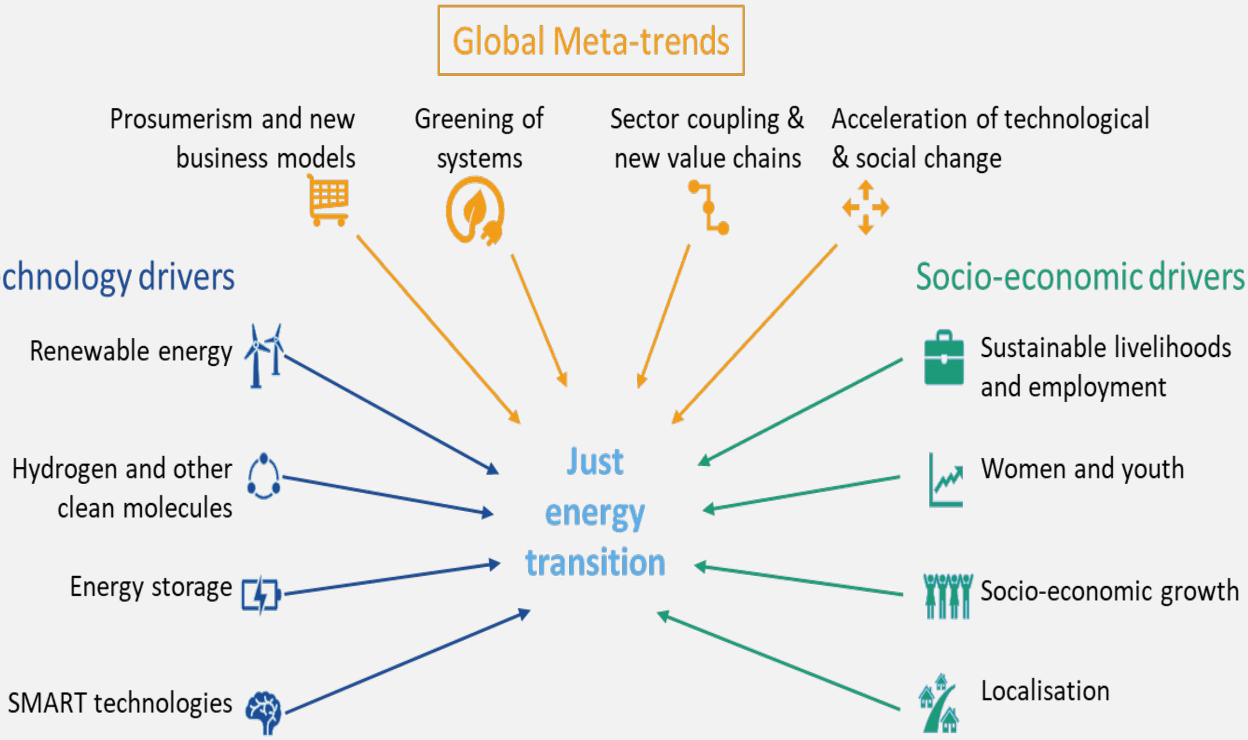


Figure 7: Global trends impacting on the energy sector in South Africa

Overall these trends are driving the energy transition towards a low carbon future. The issue of how this transition is a just one that leaves no-one behind is critical in the South Africa context and is interwoven into all the analysis and recommendations made in the report.

The additional global trends of automation (including robotics) and Artificial Intelligence (AI) were also identified as being impactful on the energy sector although not necessarily direct energy technologies (Ahmadab *et al,* 2021). These trends are covered in the next section.

Top trends impacting the South African energy system

Given South Africa's national context, it was identified that there is an overarching trend on ensuring transitions are equitable, just and sustainable, together with a further set of cross cutting/overarching trends and issues including financial drivers.

From the Phase 1 desktop study, the Phase 2 workshops and the jobs survey, a set of meta trends or drivers of the energy system in South Africa and therefore of skills requirement. were identified with some being divided into sub-trends as follows:

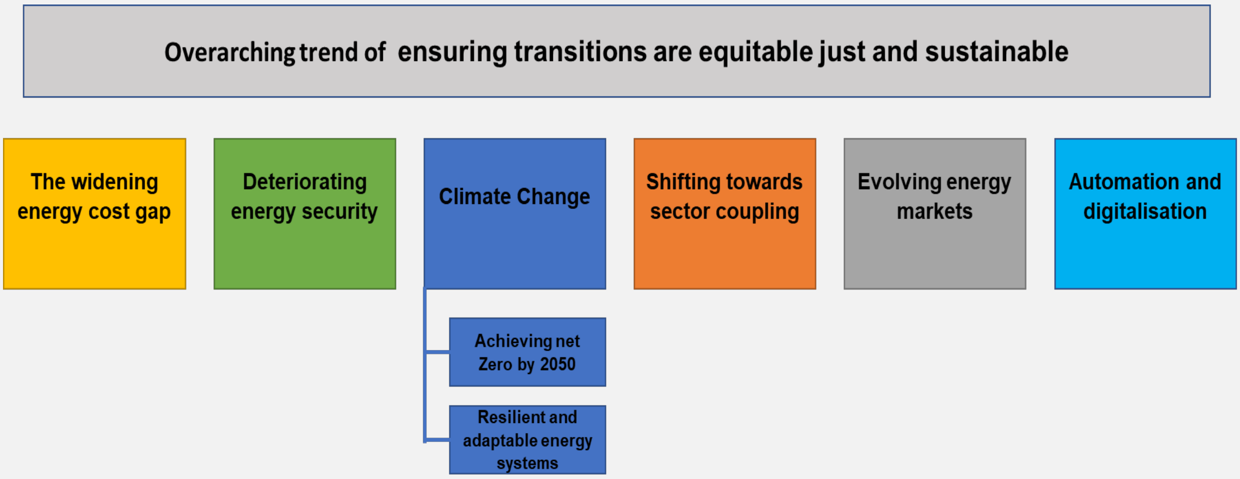
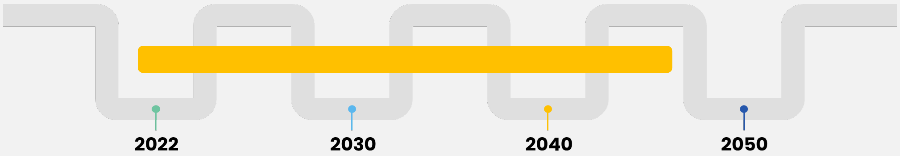


Figure 8: Top trends impacting the energy system in South Africa

The widening energy cost gap

This trend is a critical aspect in the South African context as it refers to not only energy as a driver of the economy and energy affordability, but also the distribution of income across a population as measured by the Gini coefficient. In 2021, South Africa had the highest inequality in the world, emphasising the need for an equitable, just and sustainable energy transition (Stats SA, 2018). This trend therefore shows a major tension between energy costs and a variety of socio-economic issues, despite declining renewable energy technology costs. It means that innovation around how to make energy access more affordable to low-income groups will be essential (Sarkodie and Adams, 2020).

Table 2: The trend of a widening energy gap

Trend: The widening energy cost gap	
Definition	Energy costs are in some cases declining, such as renewable energy technology costs, but overall energy prices are rising and volatile e.g., recent electricity price hikes, and fuel price volatility (Githahu, 2023, Woosey, 2021). This has implications for the energy choices business are taking in managing their energy security and costs and adjusting their business models. It also impacts poor households who may have access to energy services but cannot utilised them due to affordability issues (stats SA, 2018). Rising and volatile energy costs not only impact the economy but also government policy choices and the overall fiscus if economic growth is dampened as a result.
Time horizon	
Probability of occurring	70 90 30
What it is impacted by	Energy prices are impacted by various factors out of the control of any one country in most cases. These include: • Global energy prices. • Declining technology costs for some technologies e.g., renewables. • Geopolitical shifts. • Operational costs.
What it impacts	The widening energy gap has an impact on a broad range of issues including: • Investor confidence. • Economic growth. • Affordability. • The 'justness' of the energy transition. • Widening gap between 'haves' and the 'have nots' (disenfranchised), leading to social ills. • The incentive to adopt energy efficiency practices.
Actions or mitigation required	In order to slow and ultimately decrease this gap both government and public sectors as well as energy consumers will need to play a role: • Promotion of energy efficiency, particularly in poor communities. • Government to incentivise and subsidise where appropriate. • Enabling private sector / prosumers[1] to enable resale of excess energy. • Localisation where competitive. • Investigation of alternative fuels (incl. green fuels).

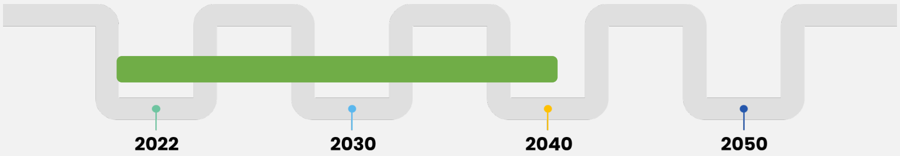
Deteriorating energy security

Given the importance of energy in economic growth this trend is of particular concern as it has knock-on implications that are significant for future growth and development and decarbonisation efforts. From

[1] "Prosumerism is the increased involvement of customers in the production process, typified by the use of customer feedback and direct design requests in high-tech industries like computer-aided manufacturing systems and the rise of customisation in both goods and services markets" (Alderete, 2017, p1).

an electricity point of view this has been declining since 2008 and for oil has been impacted by recent decisions around refineries in the country (Eskom 2022, SANEA 2022).

Table 3: Deteriorating energy security

Trend: Deteriorating energy security	
Definition	Energy security is defined by the IEA as “uninterrupted availability of energy sources at an affordable price and long-term energy security mainly deals with timely investments to supply energy in line with economic developments and environmental needs and short-term energy security focuses on the ability of the energy system to react promptly to sudden changes in the supply-demand balance” (IEA, 2022).
Time horizon	
Probability of occurring	100 90 30
What is it impacted by	Short term energy security is impacted by: ● Lack of finance and skills. ● Poor maintenance or Inadequate/bad quality maintenance ● Lack of planning. ● Poor governance. ● Human behaviour. Long term energy security is impacted by: ● Changes in technology and associated prices. ● Changes in policy impacting on energy mix and timeous decision making ● Lack of planning. ● Poor implementation.
What it impacts	Both long- and short-term security impacts: ● Adequacy of infrastructure e.g., grid constraints or lack of available generation. ● Economic growth. ● Investor confidence. ● Productivity. ● Ability to meet net zero carbon commitments. ● Affordability. ● Rise of prosumerism.
Actions or mitigation required	The actions required to address this trend will require extensive action over an extended period of time including: ● Adequate and adaptive planning. ● Enabling policy. ● Accessing adequate financing. ● Focus on implementation. ● Quality and timely maintenance. ● Management of sabotage. ● Strengthening and expanding the electricity grid and to make it specific, measurable, achievable, relevant, and time-bound (SMART) including a shift away from physical networks to smaller standalone networks.

Climate change

Achieving net zero carbon emissions by 2050

Achieving net-zero carbon emissions by 2050 is a global objective (UN, 2023). Each country in their Nationally Determined Contributions (NDC's) detail what they think they can achieve and by when. South Africa provided an update of this at COP 26 where it was highlighted that South Africa would need financial and technological support to reach net zero, as well as adaptation measures (Republic of South Africa, 2021a).

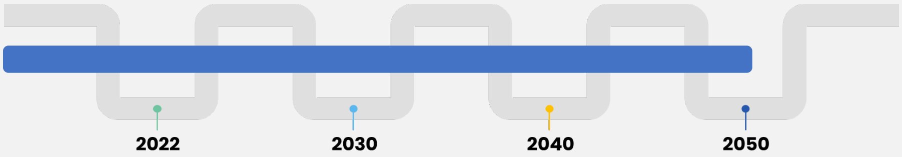
> *The timing of the transition to a low carbon economy must be in a manner that is socially just and sensitive to the potential impacts on jobs and local economies. It is in this context that engagements at global forums such as the G20 refer to 'Energy Transitions' and not 'Energy Transition' as a recognition that countries are different, and their energy transition paths will also be different due to varying local conditions. Integrated Resources Plan of South Africa 2019–20301*

Given that energy comprises a large proportion*n of greenhouse gas (GHG) emissions in South Africa, this trend has a significant impact on the energy sector.

In particular, the declining use of fossil fuels as defined in the Integrated Resource Plan (IRP) and implications for the economy, as well as opportunities for more renewables, green hydrogen and Power-to-X (PtX) products in the longer term (DMRE, 2019) and Republic of South Africa, 2021b).

The Department of Mineral Resources and Energy (DMRE) as well as the Department of Environmental Affairs (DEA) and the Presidential Climate Commission (PCC) as well as other related government departments are all working on Just Transition Frameworks, required policy and enabling environments, including mechanisms for accessing funding etc (DMRE, 2022b, PCC, 2022 and Republic of South Africa 2021c).

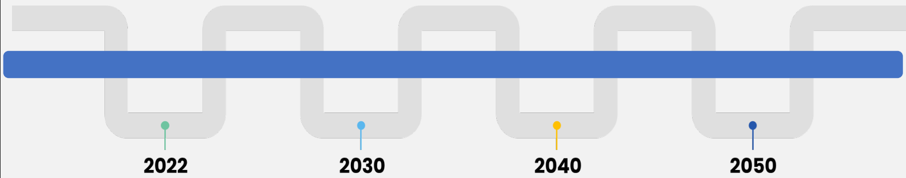
Table 4: Climate change: Achieving net zero carbon emissions by 2050

Trend: Climate change: Achieving net zero carbon emissions by 2050	
Definition	The United Nations Net-zero Climate Coalition defines net-zero as “cutting greenhouse gas emissions to as close to zero as possible, with any remaining emissions re-absorbed from the atmosphere, by oceans and forests for instance” (United Nations, 2023).
Time horizon	
Probability of occurring	90 60 20
What is it impacted by	Whether or not South Africa is able to reach net zero carbon emissions by 2050, is impacted by a number of factors including: • Energy consumption patterns. • Implementation of energy efficiency and demand side management. • The electricity mix (renewables, storage, gas, nuclear, coal). • Green hydrogen and PtX production or importation. • Financial support such as grants and concessional financing etc. • The degree of electrification of the economy. • Economic growth.
What it impacts	This trend has a wide-ranging impact on the entire country and every sector, but particularly the energy sector. Some of the impacts include: • Cost of energy and therefore the cost of doing business, and energy affordability, • South Africa’s competitiveness in global markets, • The need for supporting infrastructure e.g., ports and pipeline
Actions or mitigation required	The actions required are identified in various policy documents and is predicated on the support of developed countries, particularly funding and technology transfer: • Decisions on the pathway for a transition to cleaner fuels, including the role of gas as a transition fuel. • This means updating the IRP and Integrated Energy Plans (IEP) that should be regularly updated every 2 years as a minimum. • Extension of the current IRP to 2050. • Integration of government policy, including incentives and taxes, trade issues, education, innovation systems and planning, • National funding plan for implementation of the Just Energy Transition Investment Plan. • Cost abatement curves.

Resilient and adaptable energy systems

Changes in the climate will be exacerbated in South Africa, as it is a climate hotspot. If infrastructure is not resilient and adaptive, it will result in less energy security, higher energy costs and socio-economic implications (Climate and Development Knowledge Network, 2022 and IEA, 2022c).

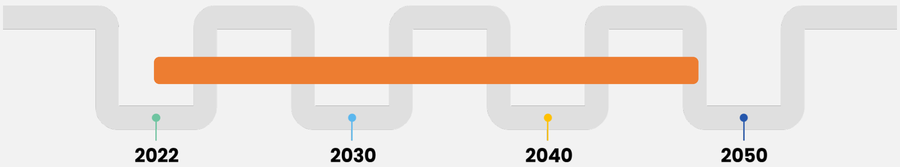
Table 5: Climate change: Resilient and adaptable energy systems

Trend: Climate change: Resilient and adaptable energy systems	
Definition	Climate change adaptation is defined as “adjustments in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects. It refers to changes in processes, practices and structures to moderate potential damages or to benefit from opportunities associated with climate change” (UNFCCC, 2023). Climate resilience is defined as “the capacity of a system to continue to function despite disturbances, either by recovery to its original condition or by some degree of transformation that changes components in a system or the relationships between components in a system” (Vasseur and Jones, 2015).
Time horizon	
Probability of occurring	70 80 100
What is it impacted by	Adaptation and resilience will be impacted by: • Increased climate disasters impacting on energy infrastructure • Mass migration impacting on planning and infrastructure needs • Access to resources • Regional actions and geopolitics
What it impacts	Adaptation and resilience impact: • Energy security • Energy affordability • Universal access
Actions or mitigation required	Actions required include: • Create awareness to lessen climate change impact • Adaptation is integrated into planning • Funding for infrastructure adaptation/new infrastructure • Modelling for energy and climate impacts, and associated research into early warning systems (disaster risk management) • Overlaying energy and climate modelling to optimise resource use and spatial planning

Shifting towards sector coupling

Sector coupling is driven ultimately by decarbonisation efforts and therefore climate change. It reinforces the global trend of sectors becoming less distinct and overlapping other sectors. In the energy sector, sector coupling is a result of end use electrification of sectors that previously used other energy sources, such as the transport sector shifting to electric vehicles (CCEESEM, 2022 and IRENA, 2022).

Table 6: Shifting towards sector coupling

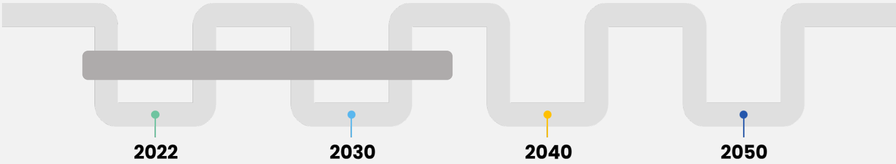
Trend: Shifting towards sector coupling	
Definition	Sector coupling is defined as "the electrification of energy demand while reinforcing the interaction between electricity supply and end-use" (CEESEM, 2022).
Time horizon	
Probability of occurring	20 75 100
What is it impacted by	Sector coupling is impacted by: • Decarbonisation targets • Carbon taxes • Cost of energy • Innovation • SMART technologies that allow for the integration of new electricity, utilising or producing technologies into the overall system
What it impacts	Sector coupling impacts: • Carbon emissions • Infrastructure requirements • Business models of incumbent companies • Demand for electricity and associated demand patterns
Actions or mitigation required	The following actions are needed: • Enabling and integrated policies • Creation of adequate infrastructure • Review of grid operation standards etc

Evolving energy markets

A global trend that has been happening since the 1990's is the move away from large centrally controlled electricity systems to decentralised smaller systems.

This has been driven by technology and policy, and means that the electricity market has many more players and a set of rules around trading. It can also mean a reduction in regulation (Baral, 2021).

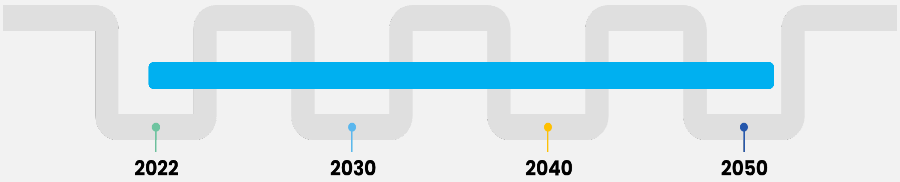
Table 7: Evolving energy markets

Trend: Evolving energy markets	
Definition	Energy markets are defined as "a market handling process specifically with the trade and provision of energy, which may refer to the electrical energy market or other energy resources" (Mousavi *et al*, 2021).
Time horizon	
Probability of occurring	60 75 90
What is it impacted by	The rate and pace of change of energy markets are impacted by: ● Government policy. ● Market size. ● Technology trends. ● Decentralisation model adopted ● Investor confidence.
What it impacts	Changes in energy markets can impact: ● Energy cost. ● Changes in energy market structures e.g. market and system operators. ● A shift in where risk is managed. ● Funding, and funding risk appetite.
Actions or mitigation required	Actions required include: ● Policy changes to enable the market. ● Development of market rules. ● Risk assessments. ● Structural changes in energy players to incorporate trading functions. ● New service providers developed for the variety of energy and related markets.

Automation and digitalisation

Automation and digitalisation are global trends that are happening at a fast pace. They are driven by the need to optimise and reduce costs. Both will have a significant impact on the energy system Digitalisation is needed for SMART energy systems and automation, which will impact on the nature and type of energy jobs. (Ahmadab *et al*, 2021 and IEA, 2017).

Table 8: Automation and digitalisation

Trend: Automation and digitalisation	
Definition	The definitions of automation and digitalisation are interlinked. According to Makeitfuture (2022), “digitisation mostly aims to support work digitally, [while] automation can make it possible to carry out this work independently. Automation can only take place on the basis of digitalisation. It can be seen as the next step in the technological and digital transformation of our time.”
Time horizon	
Probability of occurring	40 75 99
What is it impacted by	Automation is impacted by: • Global trends and need to remain competitive. • Social/labour concerns regarding potential job losses. Digitalisation is impacted by: • Level of investment in new technologies. • Cost and available funding. • Coupling to other sectors e.g. buildings and transport etc (IEA, 2017).
What it impacts	Automation and digitalisation impact on: • Increase in interconnectedness of energy systems. • Improvements in safety, productivity, accessibility and sustainability of energy systems. • New business models. • New policy required. • Available jobs and types of jobs.
Actions or mitigation required	Actions required are: • SMART technologies adopted. • Energy system management. • Innovation systems. • Skills development in this new area.

Potential implications of the top trends

These trends, although articulated separately, are all interconnected and overlap in key areas such as policy and innovation. It is shown in the trends above, what the estimated duration of the trend is as well as the estimated rate of change of that trend happening over the period 2022-2050.

It must however be noted that these trends will change in impact, pace of change and probability over time, as well as be impacted by the changes happening in the other top energy trends identified and other shifts that are global or national in nature. A consolidated picture of these trends and sub-trends is detailed below.

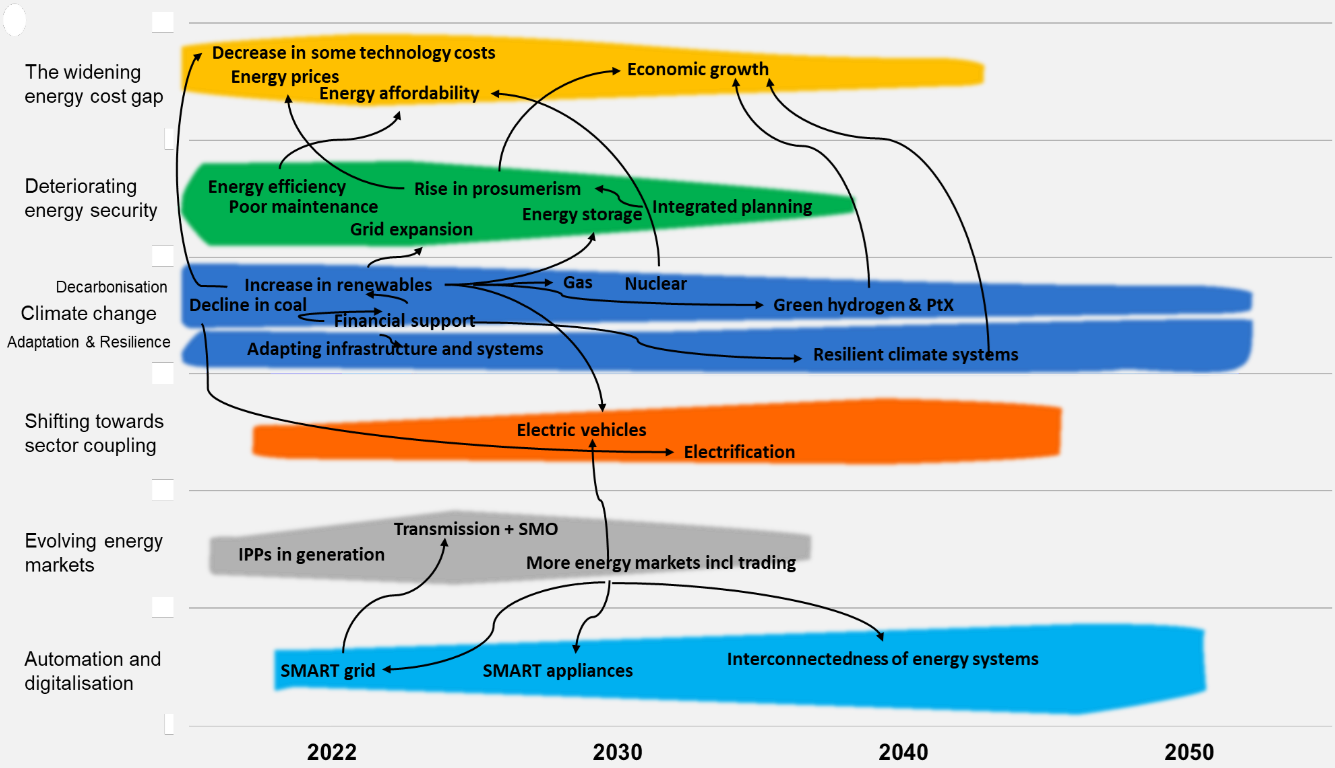


Figure 9: Consolidated trends picture to 2050

This figure shows the complexity of the landscape as well as the inter-relatedness of the issues. The central role of renewable energy is clear as well as where some key decisions will need to be taken that can change the energy sector fundamentally. It also shows how central energy security is to all the other issues and how until it is resolved, some of the other trends will be difficult to address as it is so impactful on not only the energy system but economic growth and the country itself. Automation and digitalisation are also key drivers from a skills perspective as they will result in a decline in jobs over time.

Dealing with uncertainty

Given that skills planning has uncertainty embedded in it, it is critical to identify the different uncertainties. The International Renewable Energy Agency (IRENA, 2021) identified four major types of misalignments in skills planning for renewable energy, as outlined below:

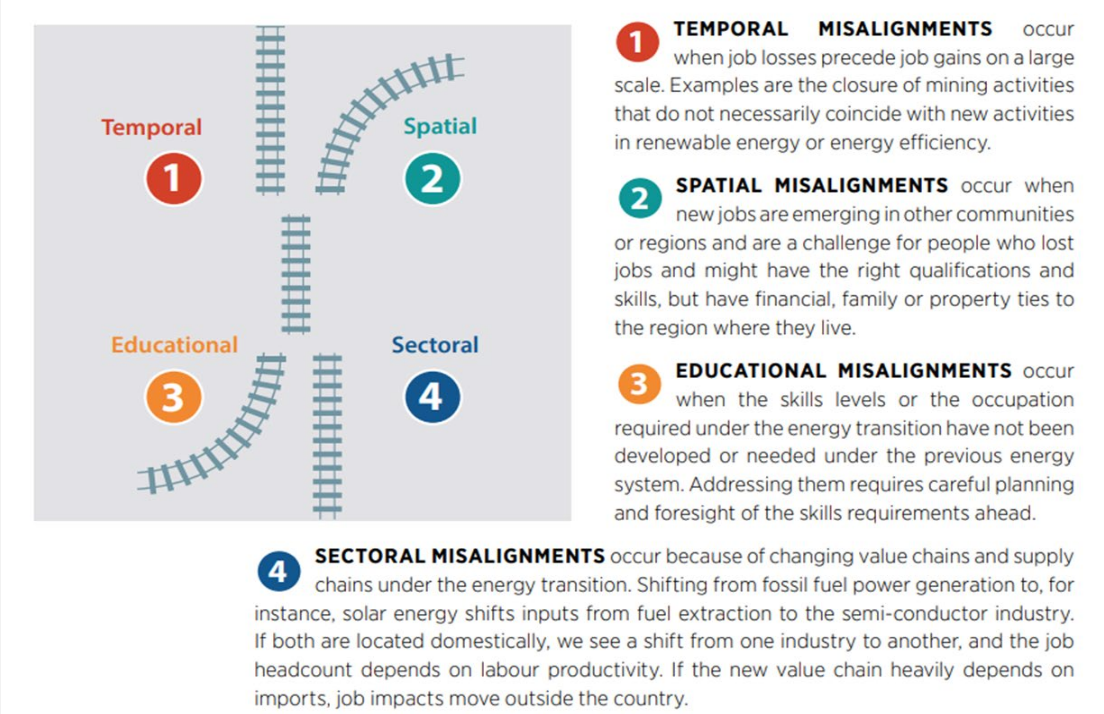


Figure 10: Misalignments in renewable energy skills development (from IRENA, 2021)

These misalignments contribute to a broader set of uncertainties that impacts skills planning. In order to assess the various uncertainties and risks that may occur over the next 30 years, a set of scenarios were developed. These scenarios allow for analysis of plausible futures that may play out, and how this will impact the key driving forces that will impact the sector in each of these futures and therefore what skills would be required. Two major uncertainties were used as the scenario extremes, namely policy (enabling and as a barrier) and economic growth (high and low). This allowed for the identification of four distinct scenarios (inspired by Beatles songs):

- Here comes the sun (high economic growth and enabling policy).
- I wanna hold your hand ((high economic growth and policy barriers).
- A hard day’s night (low economic growth and enabling policy).
- A long and winding road (low economic growth and policy barriers).

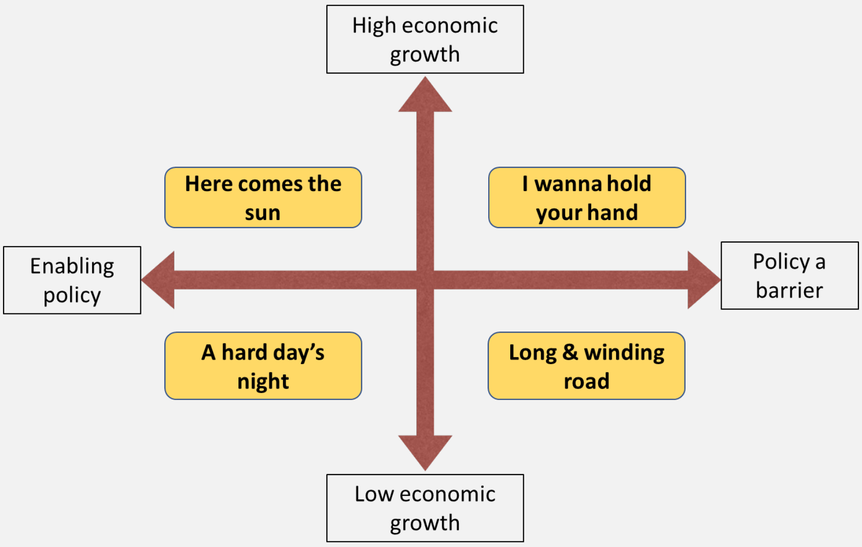


Figure 11: Scenario parameters and names

Using the scenarios, no regret options can also be identified i.e., skills that are needed in every scenario no matter what. Skills that only occur in one or two of the scenarios could be developed locally as a risk mitigation measure, or imported internationally, if necessary. Therefore, a skills strategy can be put in place that is risk (positive and negative) based. Detailed storylines were developed for each of the scenarios as detailed below:

Here comes the sun

The country is growing at >5% GDP per annum and as a result the demand for energy is rapidly increasing. Government has reviewed and integrated policy to maximise investment in the energy sector by reducing red tape, putting in place one stop shops for bundled licencing and approvals and integrating policy across all relevant departments. Due to high levels of climate financing, Eskom coal plants are shut down early and replaced with renewable energy, storage and gas in the early part of the period as a transition fuel. Finished petroleum products are imported into the country. Sasol converts its plants to green hydrogen and PtX products over time and green hydrogen and PtX investment increases significantly. Investors bring in much needed investment and climate financing. Localisation increases and SMART systems, prosumerism and open markets are in place by 2050,

I wanna hold your hand

The country is growing fast but cannot keep up with energy demand as policy development and implementation are very slow. Investors have projects but cannot get licencing and other approvals in place. As a result, there is a huge growth in self generation and prosumers as they scramble to get energy to meet their growing demands. Some companies are moving their plants just across the border to take advantage of available power in the region. Given the policy uncertainty oil refineries close and finished petroleum products need to be imported putting pressure on port infrastructure. Gas investment does not happen due to policy uncertainty, but modular renewables do as they are not dependent on as many government approvals and can be put in place quickly. Eskom stays vertically integrated and so more wheeling takes place, cutting Eskom out of the picture. Green hydrogen begins but due to policy barriers does not reach its full potential.

A hard day's night

The country is experiencing very slow economic growth of 1% and government is putting in place enabling policy to try and stimulate the economy through investment in clean energy. The country has received extensive climate funding and is replacing its coal fleet with renewables, taking advantage of the slow growth to invest in the grid and SMART technologies. Self generation and prosumers are growing albeit slowly. Green hydrogen is being strongly promoted and barriers to investment taken away. Energy security improves due to the slow growth and replacement of the old, coal fleet, Net Zero is achieved by 2050. Eskom is split into 3 companies and new players enter the market which is well run and enables energy trading across the country. Eskom is however still experiencing financial difficulties as their revenues decline.

Long & winding road

The country is in a major slump, GDP is less than 1% or negative and energy demand has fallen reducing revenue and seriously compromising the going concern status of SOE's. Government is slow to develop policy and implement it and does not consult widely, so policy is not business friendly, constraining economic growth and energy development. Investment has been hard to source; coal plants have had their lives extended and it is unlikely South Africa will meet its NDC commitments. Only a few IPPs have been added and Eskom remains vertically integrated, so an energy market has not developed despite serval attempts to set it up inside Eskom. Energy security is a major problem with ongoing loadshedding and prosumerism has exploded with everyone deciding to source their own energy. There is no money for investment in the grid, SMART or additional renewables for green hydrogen.

Figure 12: Detailed storylines for each of the energy scenarios

The changes in the key driving forces for each scenario are detailed in the table below.

Table 9: Key driving forces for each energy scenario

Key driving force	Change			
	Here comes the sun	I wanna hold your hand	Long and winding road	A hard day's night
GDP	>5%	<3%	<1%	>1%
Ease of business	High	Low	Low	High
Energy security	Low to high	Low to very low	Low to very low	Low to medium
Net-zero achieved	Yes	Maybe	No	Yes
Renewables	Strong growth	Strong growth	Medium growth	Medium growth
Gas	Strong growth	Low growth	Low growth	Low growth
Coal	Decline	Decline	Decline	Decline
Nuclear	Maybe	No	No	No
Energy efficiency	High	High	High	High
Green H_2 & PtX	High	Medium	Low	Low
Market	Many players	No movement	No movement	Some players
Prices	Moderate increases	High increases	Moderate increases	Moderate increases
Finance	Increasing	Increasing	Low	Medium
Prosumerism	Medium	High	High	Medium
Grid/SMART	Appropriate	Adequate	Insufficient	Insufficient
Localisation	High	Low	Low	Low
Just	Yes	Maybe	Maybe	Maybe

Using the scenarios, it is evident that there are a few areas where there are synergies across the scenarios (three or more) and where no regret options in terms of skills can be taken. These are as follows:

- Renewable energy (and by association Grid and SMART).
- Energy efficiency (and by association SMART).
- Prosumerism (and by association renewables).
- Finance.
- Energy security especially, in the near term.

There are those areas where there are low requirements across the scenarios where decisions will need to be taken as to whether or not skills are required to be developed or not. This category could also include when they should be developed to make sure they are either available when needed or developed too early and there are no jobs available. These include: gas, nuclear, market, and green hydrogen and PtX.

There are those areas that are declining in terms of skills namely coal and oil. Finally there are skills required to make the transition just, no matter what the scenario: Socio-economic analysis, and innovation.

These uncertainties change over time, as seen in the scenarios above. High and low uncertainties over the three time periods assessed are illustrated below:

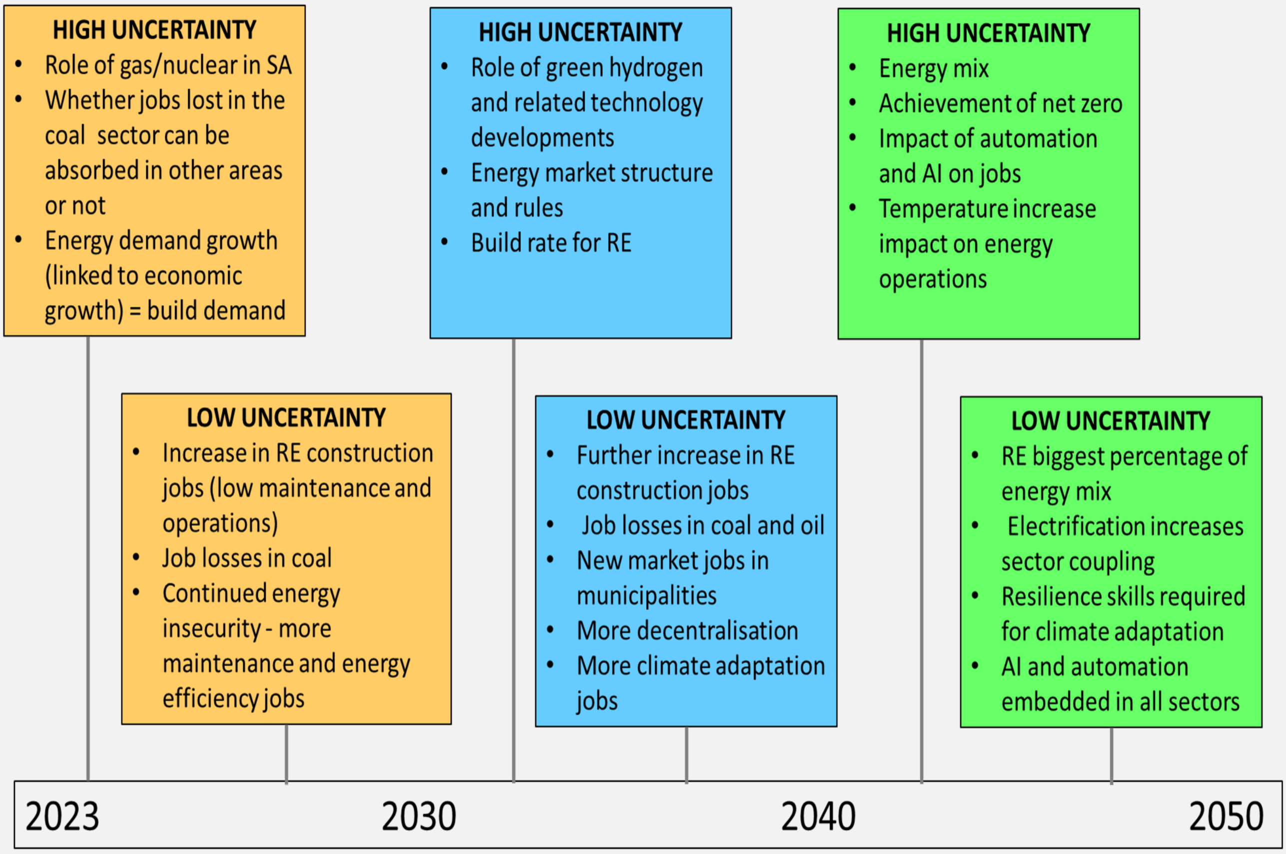
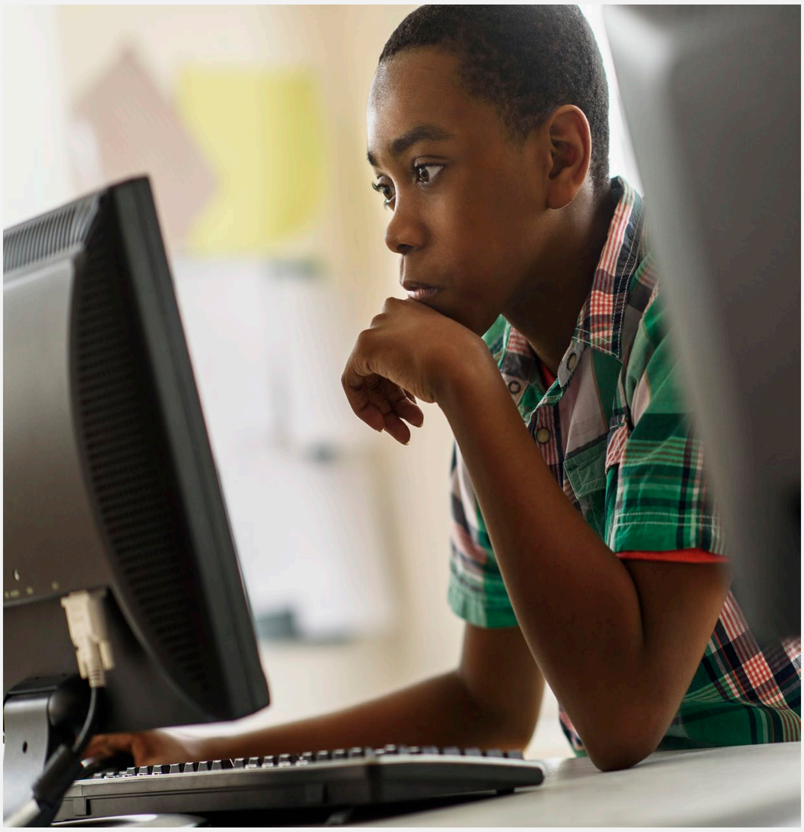


Figure 13: Changing uncertainties related to the energy sector over time

IMPLICATIONS OF KEY TRENDS ON WORK

Introduction and purpose



This section provides an overview of the current energy sector labour market, reviews current and future energy job demand, implications on the world of work and the post-school education system. It is important to understand the current labour market to assess the likely impact a just transition will have on the world of work - occupations and skills likely to go into decline, those that require upskilling or reskilling, and 'new' jobs.

Data gathered through document research, the workshops and job advert analysis provided detailed insights into current and future occupation and skills requirements (demand). These are presented against each of the identified trends, as well as the implication of the trend on the world of work.

To ensure that the energy system can be adequately resourced during the transition process, it is also important to understand the implications the current and future occupation and skills requirements will have on the country's post-school education and training (PSET) system.

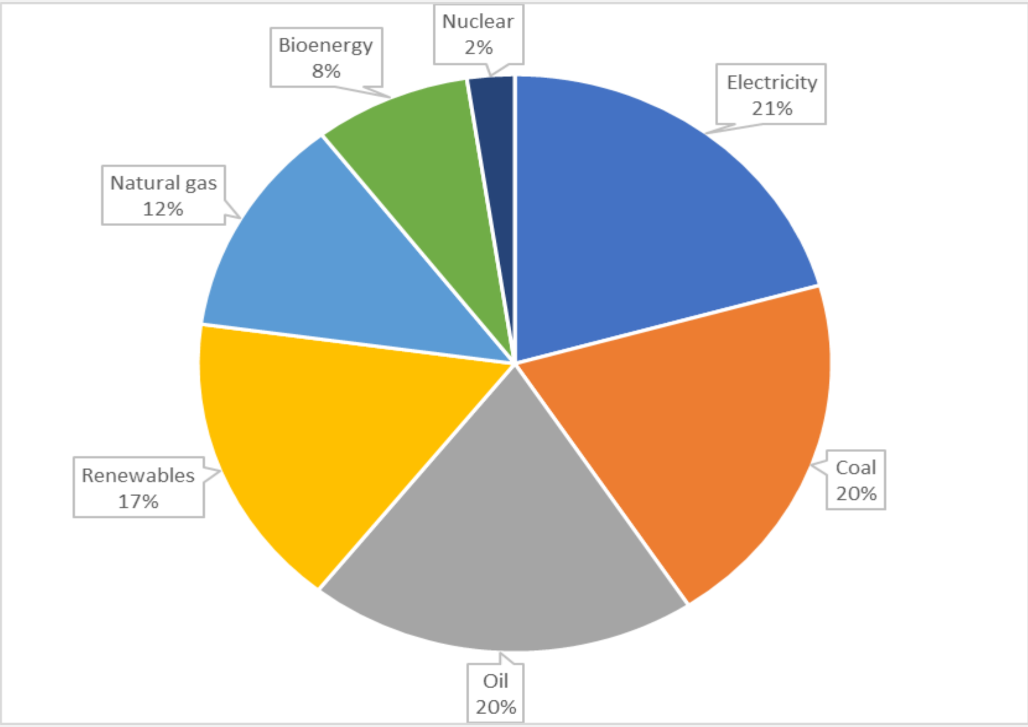
In this regard, a detailed identification and analysis of current energy related courses offered in the country was undertaken. This illustrates current education provision, and when correlated with current and future employer occupation and skills demand it is possible to identify areas that are adequately covered, or where skills gaps exist. An assessment of supply versus demand on the PSET system is presented by core trend.

Status of the energy labour market

Global energy labour market and employment trends

In 2019, it was estimated that 41 million people were employed globally in the energy sector, with an additional 24 million indirect employees involved in e.g. vehicle manufacture and energy efficiency (IEA, 2022).

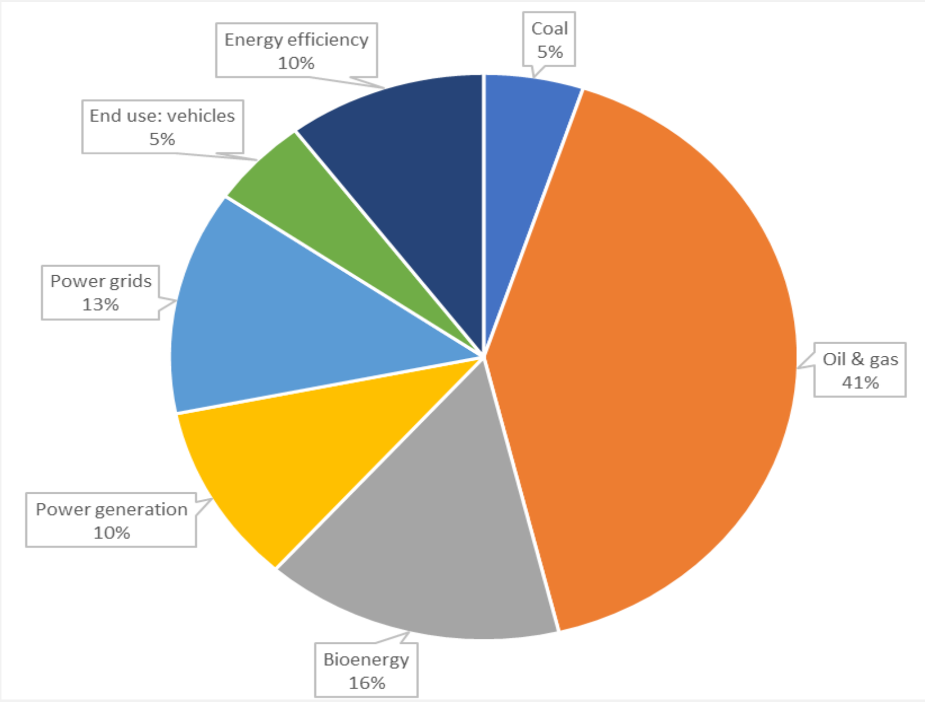
The figure below illustrates the global employment profile by energy sector in 2019. It indicates the main sectors of employment are end use vehicles (21%), oil and gas (18%), energy efficiency (17%) and power generation (17%) (IEA, 2022).



Source: Derived from IEA (2022).

Figure 14: Global energy employment profile, by sector (2019).

In comparison, Africa's energy sector employment profile illustrates some differences to the global profile (see the figure below). Most notably, is the dominance of the oil and gas sector as an employee (41% of total employed). However, in the sectors of energy efficiency and end of use vehicles, the continent employs significantly less than the global average. This indicates a focus on fossil fuel and power generation activities as the main employers, with fewer employees involved in clean energy. This is the reverse for Central and South America, Europe, China, India and Asia Pacific (IEA, 2022).



Source: Adapted from IEA, 2022.

Figure 15: Africa energy employment profile, by sector (2019).

Regarding global renewable energy sector employment, an estimated 12.7 million people were employed directly and indirectly in 2021 (IRENA, 2022). Solar dominates employment numbers (34% of total employed), followed by liquid biofuels (19%), hydropower (19%) and wind energy (11%) (IRENA, 2022). In Africa, an estimated 320,000 people were employed in the sector in 2020, of which 23% were in southern Africa (Kamer, 2022)

In terms of employment trends in the global energy sector, the IEA (2022) suggests that clean energy transitions and decarbonisation of energy are the predominant trends reshaping global energy employment. For example, it is estimated that 50% of total energy workers are employed in clean energy, which indicates the significant growth in this area (IEA, 2022). This is corroborated by IRENA (2022), who suggest employment in the renewable energy sector continues to grow, and has grown by 10% since 2012. Most growth is in solar photovoltaics (PV), bioenergy, hydropower and wind power.

By 2030, this transition to clean energy is predicted to generate approximately 10.3 million new jobs (from 2021) globally (Wallach, 2022), with energy efficiency, cars, power generation, grids, bioenergy and end-use renewables all gaining over 1 million new jobs (see Table below). As a counterbalance, most job losses in this transition are going to be witnessed in coal and oil and gas, as fossil fuel demand decreases (Wallach, 2022).

Table 10: Estimated job gains/ losses associated with the transition to clean energy (2021-30)

Clean energy jobs by sector (2021 to 2030)		Jobs gained (million)	Jobs lost (million)
Efficiency		3.2	0
Cars		2.6	0
Power generation		2.6	-0.3
Grids		1.6	0
Bioenergy		1.2	0
End-use renewables		1	0
Innovative technologies		0.9	0
Critical minerals		0.2	0
Coal		0	-0.6
Oil and gas		0	-2.1
Total		13.3	-3

Source: Adapted from Wallach (2022).

Other employment trends identified for 2022 include (IEA, 2022):

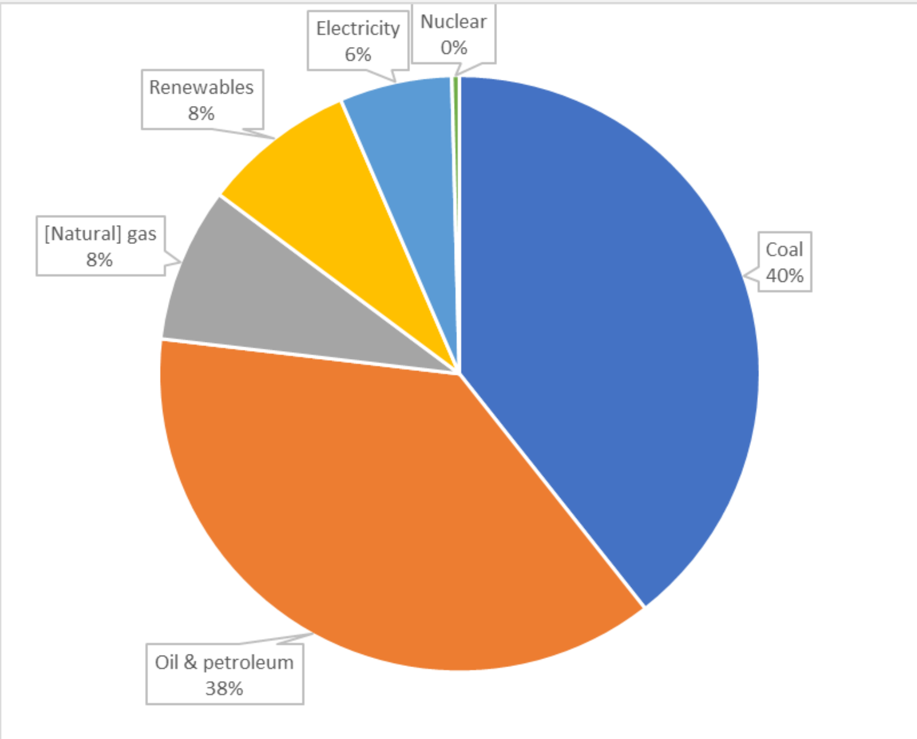
- 60% of the workforce is employed in construction of new projects e.g., building power plants, bringing oil wells online and laying pipelines, manufacturing cars, carrying out efficiency retrofits and installing efficient electric heat pumps.
- The need to transfer fossil fuels workers to low-carbon sectors and activities. With energy decarbonisation employment opportunities set to grow and outweigh the decline in fossil fuel jobs.

From a skills level perspective the IEA (2022) notes that the sector, in the main, requires higher-skilled workers, with jobs in research and development for new projects on the increase.

Gender is also a core dimension of employment in the sector. The percentage of women employed is considered to be relatively low at 22%-25%, in comparison to other sectors (IEA, 2022; Trace, 2020). In sub-Saharan Africa women are estimated to comprise less (16%-20%) than the global average in the sector (Stolar, 2021). Within the renewable energy sector, it is suggested that percentage is slightly higher, at 32%, and likely due to the more multidisciplinary nature of the sector (IRENA, 2019).

South Africa energy labour market and employment trends

Drawing on the various statistics on the number of people employed per main energy sector in South Africa, it can be estimated that 667,300 people are directly and indirectly employed across the sector. The coal, and oil and petroleum sectors employ the most people. The Figure below provides an overview of estimated employment split by the energy sector in South Africa. It should be noted that employment figures in South Africa's energy sector, especially renewable energy, are not always easy to ascertain. Renewable energy is often presented as potential rather than current employment (Hermanus, 2022; Meridian Economics, 2018).



Sources: Rennkamp and Bhuyan (2017), DMRE (2022), Hako (2022), Hermanus (2022), IRENA and ILO (2021), Sapia, (2019), Skidmore (2021), Statista (2022), StatsSA (2022a).

Figure 16: Estimated South African energy sector employment profile

While it could be assumed that a transition to cleaner and renewable energy will have begun to realise the predicted job losses in coal, and the oil and petroleum sectors (discussed further under Climate change - achieving net zero by 2050 in the section below), this has not necessarily been the case. For example, for the period 2012 to 2019, the coal mining sector saw an increase of 17,100 jobs (Khumalo, 2021), and the oil and petroleum sector continued to employ 1.5% of the country's total workforce in 2019 (SAPIA, 2019). While jobs in these two sectors appear to remain stable, the decrease over time in coal-fired power plants could see employment in the coal sector decline by almost 50% by 2050 (Okunlola et al., 2019).

This increase however, has not been witnessed in the electricity sector, which has seen a decline of approximately 4,500 jobs since 2012 (StatsSA, 2022a). Some of these losses may be attributed to the impact of Covid-19 (Jenkin et al., 2021). While this decline is an overarching trend within the electricity sector, Eskom - who are a major employee - have to the contrary increased their employee numbers from 30,000 to 40,000 between 2008-2019, yet productivity has decreased (Anon, 2019). In an interview with Eskom's 2019 Chief Operating Officer, Oberholzer indicated that the utility does not have the funds to retrench people, as it is too expensive to do so. If they were to retrench people, this would see major job losses of between 10,000 – 14,000 people (Anon, 2019). Given this large-scale impact, the utility finds itself in a difficult situation. One of the solutions is to improve performance through optimising the workforce, or to transition those currently in Eskom (who have immense experience, knowledge and skills) to other industries that have a positive outlook, e.g., renewables.

While current renewable energy employment figures are estimates for solar and wind Renewable Independent Power Producer Programme (REIPPP) projects only (see Table 11 above), the sector is considered to have vast employment potential (Okunlola et al., 2019), with much emphasis placed on potential job creation. Research suggests that a scale up in renewables could see a 40% increase in jobs in the sector by 2030 - the equivalent of 580,000 job years, and 1.2 million along the renewable energy value chain (Okunlola *et al*., 2019).

Most prominent job-related activities across the sectors

For a skills roadmap it is useful to understand where along a sector's value chain jobs currently sit, as it is these jobs that are most likely to be impacted by a just transition of the sector. These are highlighted, where identified, in the Table below:

Table 11: Predominant activities associated with jobs in South Africa's energy sectors

Energy sector	Predominant job activities
Coal	The majority of jobs in this sector are associated with coal mining and transportation (Patel et al., 2020).
Electricity	A variety of jobs are associated with the generation, transmission and distribution of electricity. These include those involved in customer services, engineering, environment and safety, finance and management, human resourcing, maintenance and operations, marketing, performance and works planning, and property management (Eksom, 2023).
[Natural] gas**	While the exploration and extraction of gas is not a major activity in South Africa, it is considered an area of significant employment potential as exploration companies set up offices in South Africa to exploit the country's gas reserve potential (MOGA, 2018).
Nuclear	Currently most jobs in the sector are associated with the operation of the Koeberg nuclear power plant (Rennkamp and Bhuyan, 2017).
Oil & petroleum (liquid fuels)	Retail forecourts and convenience stores employ the majority (52%) of people in the sector, followed by financial and business services (12%), agriculture (11%), transport (5%) and mining (4%) (Sapia, 2019).
Renewables	The majority (80%) of jobs registered under REIPPP in 2020 occurred in construction, which provides less permanent employment, and can be experienced in peaks and troughs, which are often linked to funding cycles. The remainder of the jobs are predominantly permanent, and within operations and maintenance IRENA and ILO (2021).

Gender and wages

With regards to gender, the majority of employees in the South African electricity and gas sectors are male, with 35% of women making up the electricity workforce, and 26% in the gas sector (StatsSA, 2022a). This correlates with, although could be considered slightly higher than, the global average for women in the broader energy sector (22%-25%) (IEA, 2022; Trace, 2020), and higher than the sub-Saharan energy sector (16%-20%) (Stolar, 2021). However, within the renewable energy and oil sectors, women make up as little as 10% of REIPPP projects (IRENA and ILO, 2021) (compared to the global average of 32% (GETI, 2021, IRENA, 2019)) and less than 15% in the oil sector (Patel et al., 2020).

From a justice and/or decent work perspective, monthly earnings could be indicative of fair pay within the sector. The estimated average monthly earnings for employees in the electricity, gas and water supply sector was estimated at R44,279.00[2] per month (StatsSA, 2022). The highest across all sectors. This is significantly higher than, for example, the manufacturing (R19,994.00/month), construction (R19,775.00/month), and Wholesale and Retail (R15,747.00/month) (StatsSA, 2022). Jobs drawing the highest salaries in this sector are involved in 'manufacturing coke oven products, petroleum refineries,

[2] This excludes bonuses and overtime (StatsSA, 2022).

and processing of nuclear fuel' (BusinessTech, 2022). Within the electricity sector, monthly wages can vary significantly, with average monthly salaries within Eskom ranging from e.g., R6,030.00 per month for a general worker, and R48,220,00 per month for a Senior Supervisor (Indeed, 2022). It is possible that these higher than average monthly earnings are related to the level of education and skills required (Jenkin et al., 2021).

Aside from nuclear employee incomes illustrated above, the rest are situated within or are inextricably linked to the fossil-fuel sector. Which correlates with the 'enormous number of jobs' in carbon heavy sectors in South Africa, such as coal mining and the liquid fuels sectors (Burger, 2022, Cannard, 2020) (see Figure 15 above). As a result, the trend to shift towards net zero by 2050 through a reduced reliance on coal and liquid fuels will have both opportunities and risks for those currently employed in the sector. This is explored in more detail below.

Implications of the core trends on the world of work, occupations and skills

This section outlines the potential shifts and changes in the labour market that could be experienced should and when the trends identified in Section 2 are realised. This is done through the lens of how each identified trend will impact the world of work in South Africa's energy sector, with a particular focus on occupations and core jobs impacted. This reflection on the world of work in turn informs the likely occupations and skills required along a short, medium and long-term time horizon. Such an understanding can inform the planning and provisioning of education and training to develop a 250,000 strong or more workforce (Burger, 2022) that has the capacity and capabilities to respond to the trends and requirements to transition the energy sector to one that is just, sustainable and resilient.

This overview is presented within the current labour market context - one in which fossil-fuel-related jobs are the most dominant, yet energy policy and vision requires a significant shift to decarbonisation and net-zero by 2050. Given that decarbonisation of the sector requires a major shift away from and/or reduction of fossil-fuels in the country's energy mix, this will have significant implications on current jobs in the oil and gas, and coal sectors. In turn a growth in clean and renewable energy provides an opportunity for those currently employed in fossil-fuel sectors to potential transition to these growth sectors, and the creation of new jobs. This context is reflected and acknowledged in the implications of the identified trends in the world of work tables below.

It is important to note that while interpreting the list of occupations along the time horizon that these are indicative of those likely to be most in demand in a given period, but this will depend on various scenarios (e.g. recognition of gas in the energy mix) and rate of implementation.

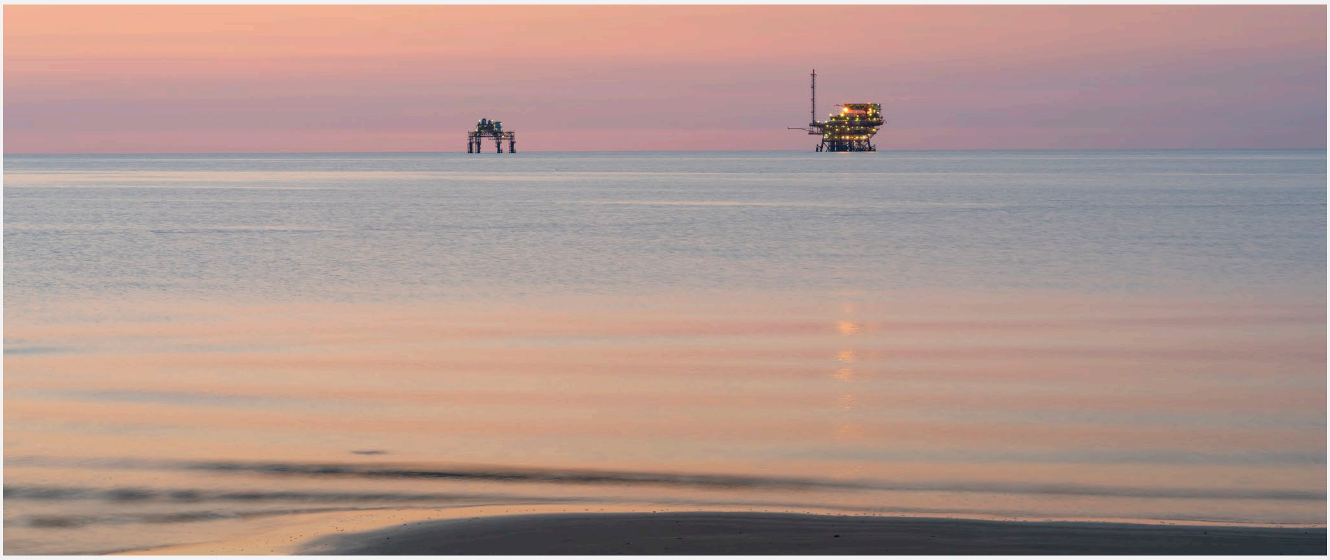
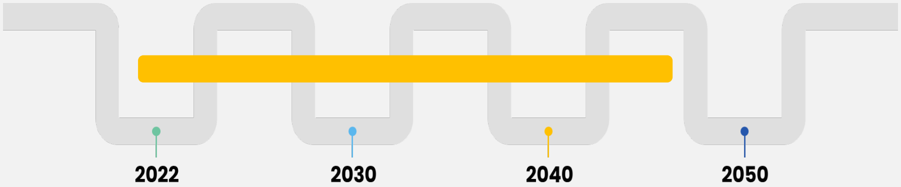
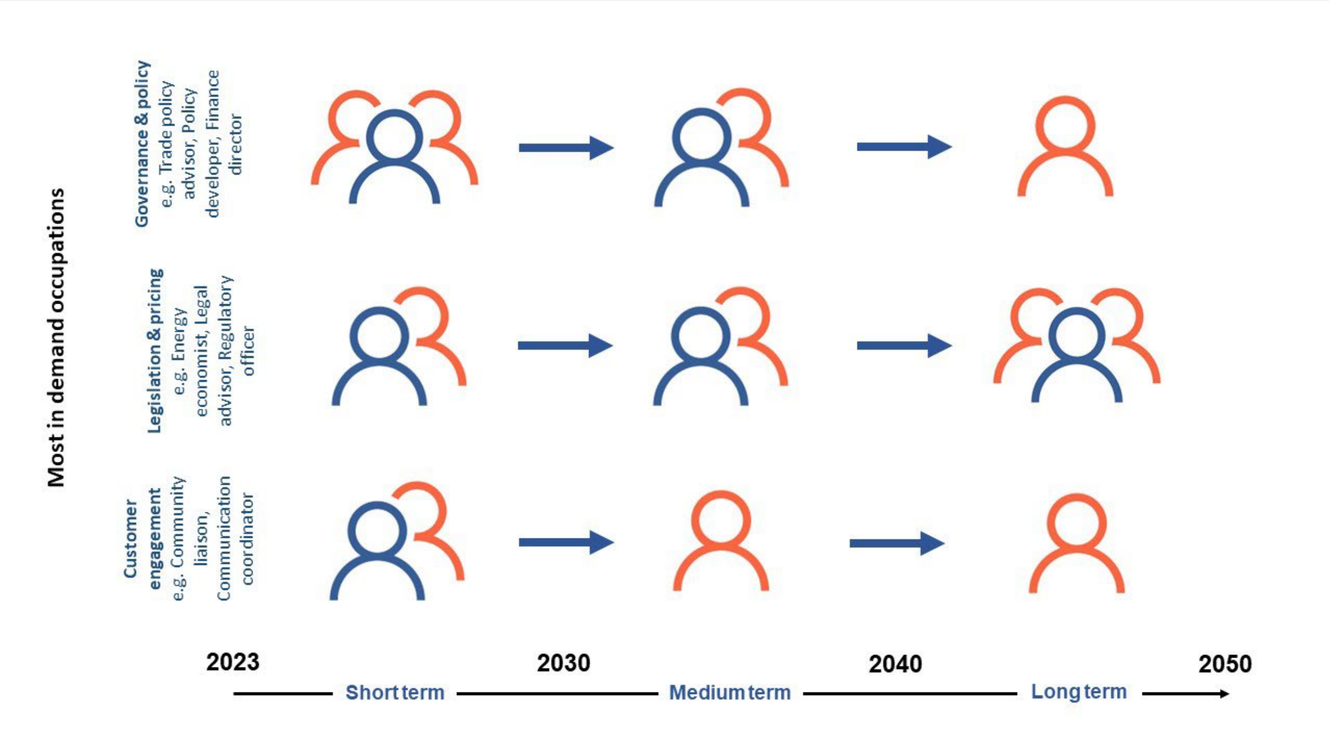


Table 12: Impact of the widening energy cost gap on the world of work, occupations and skills

Trend: The widening energy cost gap	
Time horizon	
Impact on the world of work	● Increased energy prices impact vulnerable households - policy makers need to ensure protection measures e.g., laws and subsidies to mitigate social impact of rising prices. ○ High prices can result in theft or an inability to pay (SADC, 2020). Energy safety nets can be considered to support low-economic communities with schemes like free basic electricity. In addition, the implementation of theft protection mechanisms need to be put in place. Individuals will be required to advise and implement such mechanisms. ● An increase in the price of electricity can have a short-term negative impact on workers in all economic sectors, notably those that are energy intensive e.g. industrial (chemical and petrochemical, and iron and steel) and mining sectors (DMRE, 2022a). However, increased prices can lead to an optimisation in energy use resulting in cost savings and therefore job retention. Vulnerability to energy price shocks will require: ○ Employers to improve management or control of energy consumption, and implement energy efficiency policy and reduction activities, and ○ Householders to better understand and reduce their energy usage. ● Government officials (advisors) and regulators are required to develop and implement energy sector master plan(s) to recognise universal access to reasonably priced electricity, develop and advise on electricity tariffs, enable the trading of privately produced energy to generate income, and to incentivise energy efficiency practices, especially in energy intensive industries.
Minor occupation groups	● Legislators and Senior Officials ● Managing Directors and Chief Executives ● Professional Services Managers ● Mathematicians, Actuaries and Statisticians ● Finance Professionals ● Social and Religious Professionals ● Sales, Marketing and Public Relations Professionals ● Legal Professionals ● Regulatory Government Associate Professionals ● Legal, Social and Religious Associate Professionals

The most in demand occupational groups associated with this trend are those involved in governance and policy, legislation and pricing, and customer engagement. Given the urgent need to deliver affordable and universal electricity access initial focused policy and implementation is required in the short term. While these roles will also be required long-term, the extent of the activity, and therefore employment demand for e.g., policy advisors will decrease.

The reverse is the case for those involved in legislation and pricing, who while being involved in informing policy will become more active in implementation, such as developing appropriate legislation and regulation, or pricing structures. In the case of occupations involved in customer engagement, these occupations are likely to be most active in the short terms, as community liaisons engage with energy users to determine affordability challenges and implementation plans.

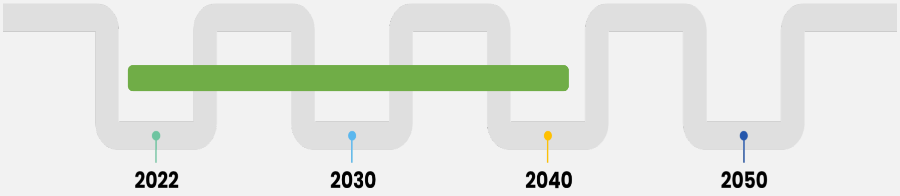


Source: Author derived.

Figure 17: Most in demand occupations for the widening energy cost gap

NOTE: Human icons present an illustration of scale of demand from one person suggesting the group of occupations will be in demand but not in large numbers, and six people denoting large occupation demand and large numbers of individuals required to implement or mitigate a trend.

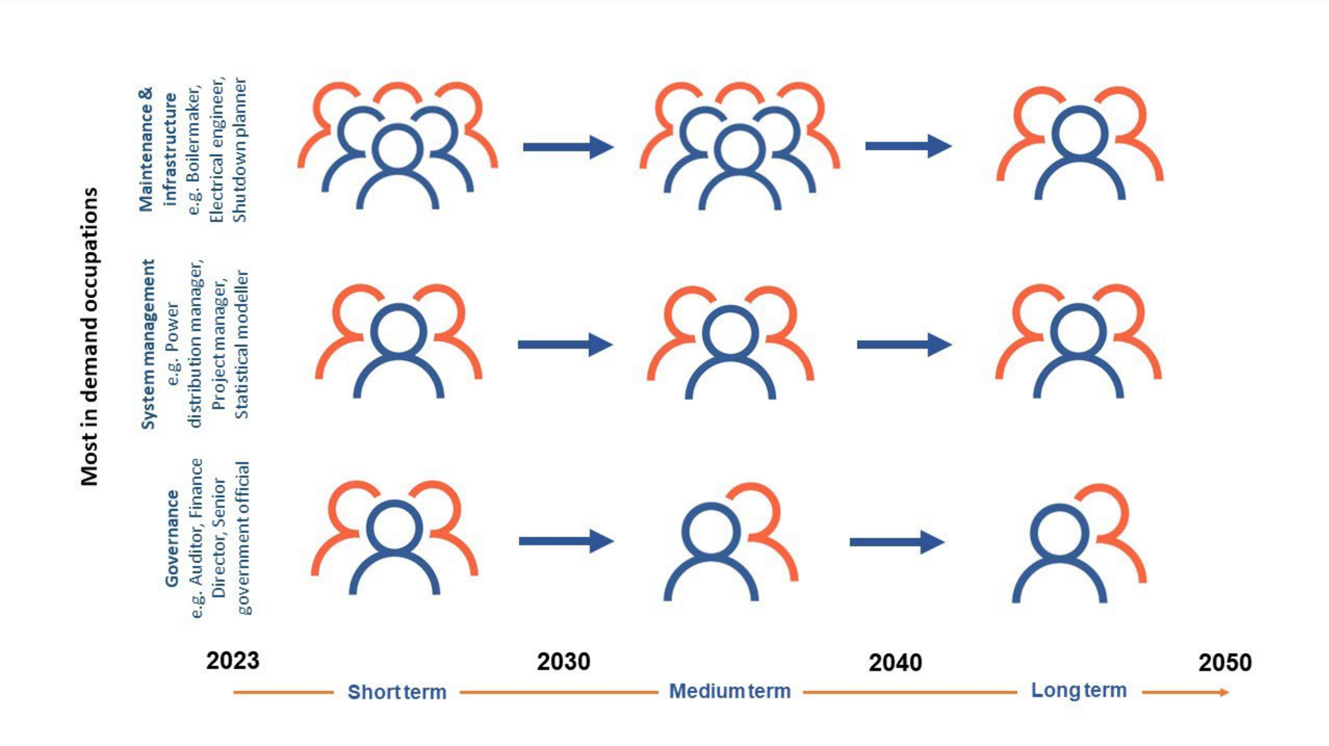
Table 13: Impact of deteriorating energy security on the world of work, occupations and skills

Trend: Deteriorating energy security	
Time horizon	

Impact on the world of work	• To transform the generation of electricity into an effective and efficient operation that the country's businesses and population can rely on, good leadership and management, union negotiation; policy development; planning, implementation (including quality control) and monitoring; risk mitigation (including security); financing; coordination and core maintenance skills are required (Peyton, 2022).
	  ○ Given the need for maintenance skills (an estimated shortfall of 40,000 artisans in the country), emphasis on electrical / maintenance technician and planning training is critical (accredited / certified) (Alphonsus et al., 2021).
	  ○ Recruitment of skilled personnel, including former Eskom personnel, to work with current permanent teams to resolve urgent issues and to transfer skills to permanent staff (Gerber, 2022).
	• With the transmission grid facing constraints there is a need to expand the grid, to incorporate renewables and mini grids (see Climate change - achieving net zero by 2050 trend below). This will require individuals with the knowledge and skills to seek investment; finance, coordinate and implement the expansion. It is likely that these skills will be required in more decentralised nodes of activity e.g., districts and municipalities (see the evolving energy markets trend below).

Minor occupation groups	• Legislators and Senior Officials • Managing Directors and Chief Executives • Mathematicians, Actuaries and Statisticians • Engineering Professionals • Architects, Planners, Surveyors and Designers • University and Higher Education Teachers • Vocational Education Teachers • Finance Professionals • Legal Professionals • Physical and Engineering Science Technicians • Process Control Technicians • Financial and Mathematical Associate Professionals • Sales and Purchasing Agents and Brokers • Machinery Mechanics and Repairers • Electrical Equipment Installers and Repairers

The most in demand occupational groups associated with this trend are those involved in maintenance and infrastructure, system management, and governance. Given the current electricity crisis and need to reduce breakdowns there is and will be an immediate large-scale need for those involved in maintenance and repair of power generation plants and infrastructure. Into the medium term offline planned maintenance will remain critical, not only for Eskom, but also IPPs and large energy users, such as mining and manufacturing. As the initial critical large-scale maintenance and repair activities are completed, standard maintenance planning and implementation activities and roles will be require to ensure levels of efficiency and output are maintained. The same trajectory of demand is expected for those involved in managing the energy system, however, it is anticipated that not as many individuals within management and operations will be required as those involved in maintenance and repair. Regarding governance, these roles are critical in the immediate short-term for steering South Africa’s energy system out of the current crisis, this includes e.g. senior ministers, chief operating officers, finance directors, auditors and energy specialists. While still required in the medium and long term, the intensity of demand should drop off.



Source: Author derived.

Figure 18: Most in demand occupations for deteriorating energy security

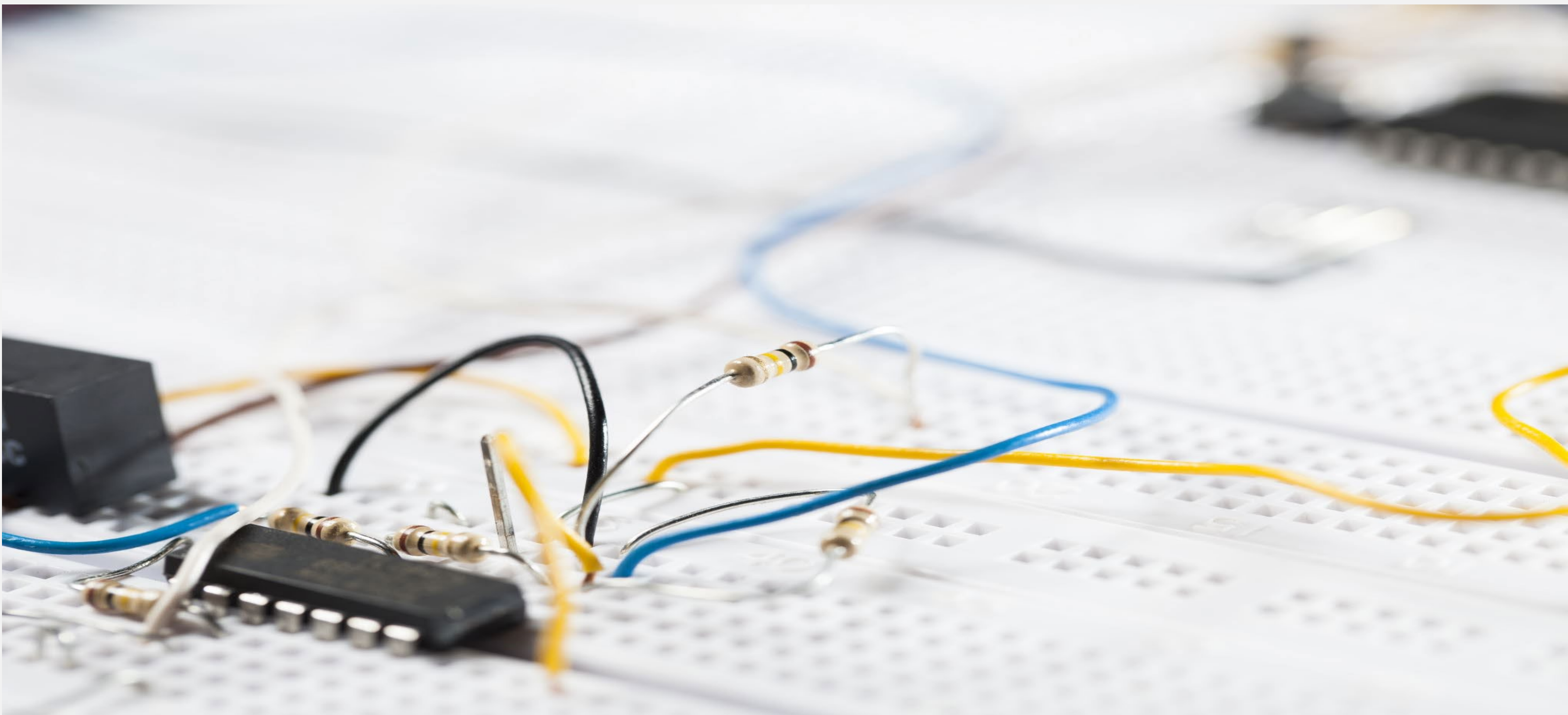
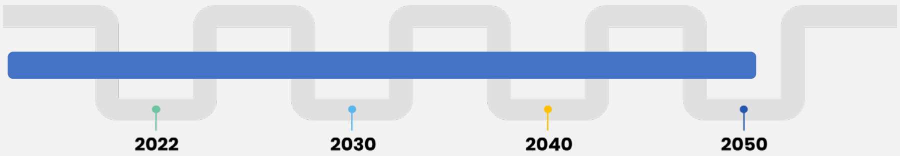


Table 14: Impact of climate change – net zero on the world of work, occupations and skills

Trend: Climate change: Achieving net zero carbon emissions by 2050	
Time horizon	
Impact on the world of work	• A transition to low- and net zero carbon will require a change in the country's energy mix, new technologies, new energy pathways and revised cohesive plans, aligned policy, new operating and integration models and new employment pathways. This will present new work opportunities, likely an increase in jobs (estimated 180,000 jobs by 2035 and 468,000 jobs by 2050 via decarbonisation of the energy sector), but also timing and employment risks. Long-term transition planning, guidance and financing is critical (Burger, 2022; Cozzi and Motherway, 2021; Hanto et al., 2021; Okunlola et al., 2019), and requires up to date, aligned and clear vision and policy e.g. Integrated Resource Plan (IRP) (Creamer, 2022; Evans, 2021). • This significant shift will require a detailed review of current education and skills provisioning in the country and how it aligns with short, medium and long term skills demands. This is likely to result in the refinement and development of new education programmes, courses, research and curricula (Heppelthwaite et al., 2022). Shift from fossil fuels / decarbonisation: • A shift away from and reduction in use of fossil-fuels will result in reduced employment and affect local communities associated with coal mining and logistics, and most likely the oil and gas sectors too (Patel et al., 2020; Skidomore, 2021)[3]. o The shift away from coal is estimated to result in significant job losses in the sector - 48% by 2050 (Montmasson-Clair 2021; Okunlola et al., 2019). This shift will affect management and professional, process operators, maintenance personnel and artisan, truckers and clerical personnel working in these sectors. While most of these occupations listed are likely to find alternative employment outside these sectors, coal miners and process operators will be the most affected and/or unlikely to find like-for-like positions. Approximately 80,000 coal miners and 120,000 value chain jobs are at risk. This is compounded by 80% of the coal workforce having a matric or less. Therefore education, upskilling and reskilling will be critical to ensure e.g. coal miners can easily move into other sectors (Burger, 2022; Gatticchi, 2020; Hanto et al., 2021; Montmasson-Clair, 2020; Patel et al., 2020). o This shift will also have an impact on the localisation of jobs e.g. from Mpumalanga to Northern Cape (solar PV). There is a need to ensure no one is left behind e.g. alternative job provisioning in current location, or relocation is considered, well planned and targeted in communities that are impacted (Cozzi and Motherway, 2021; Hanto et al., 2021; IRENA and ILO, 2021). o Skills will be required in labour force and community stakeholder engagement and negotiation to realise a just transition for this sector of the workforce and associated communities (Patel et al., 2020). o Decommissioning or retrofitting of coal-fired plants will require unique skills and knowledge, as well as upskilling of the current coal-fired power workforce (EWSETA, 2021; Meridian Economics, 2018).

[3] Due to the numerous strands of occupation and skills considerations and contexts, this report cannot do the impact on fossil-fuel jobs justice. However, the authors wish to acknowledge the significant work undertaken in this area in the COBENEFITS project (see e.g., Okunlola et al., 2019), the Presidential Climate Commission (see e.g., PCC, 2022) and TIPS (see e.g. Montmasson-Clair, 2020 and 2021).

	Renewable energy (solar, wind, biomass): ● The growth of the renewable energy sector will require the necessary jobs and skills to fulfil the sector's growth potential, including jobs in planning and strategy, research and development (R&D), technology manufacture, installation and construction, operations, management and maintenance, sales and marketing, and associated clerical and technical work. Increasing the share of renewables will increase employment opportunities (Cozzi and Motherway, 2021; Okunlola et al., 2019), with this demand partially substituting the decline in coal-related jobs (Hanto et al., 2021). While predictions for renewable energy job creation numbers vary, the following have been suggested: Wind (130,000 direct and in-direct up to 2030) (Burger, 2022). ● Currently there is a scarcity of specialist renewable energy technical and managerial skills. This will require the education, training and upskilling of e.g. engineers and technicians to shift into renewables (BusinessTech, 2022a; Altgen, 2021). ● There is likely to be a shift away from corporate monopolies to privatisation and decentralisation. More responsibility will fall on local municipalities to procure, negotiate and set tariffs, trade and manage the electricity generated within their jurisdictions (see the Evolving Energy Markets trend below). Clean energy (automotive, industry, green hydrogen, nuclear) ● Clean energy, such as efficiency, new technologies and automotive will require new roles or upskilling of the existing workforce in industry to manufacture, procure, install, maintain and monitor low-emission products e.g. electric vehicles, appliances and technologies e.g. green hydrogen (Cozzi and Motherway, 2021). Energy efficiency: ● See the widening energy cost gap trend above.
Minor occupation groups	● Legislators and Senior Officials ● Managing Directors and Chief Executives ● Business Services and Administration Managers ● Sales, Marketing and Development Managers ● Manufacturing, Mining, Construction and Distribution Managers ● Life Science Professionals ● Engineering Professionals ● Architects, Planners, Surveyors and Designers ● University and Higher Education Teachers ● Vocational Education Teachers ● Finance Professionals ● Sales, Marketing and Public Relations Professionals ● Legal Professionals ● Social and Religious Professionals ● Physical and Engineering Science Technicians ● Mining, Manufacturing and Construction Supervisors ● Process Control Technicians ● Sales and Purchasing Agents and Brokers ● Regulatory Government Associate Professionals ● Sheet and Structural Metal Workers, Moulders and Welders ● Machinery Mechanics and Repairers ● Electrical Equipment Installers and Repairers ● Mining and Construction Labourers

The most in demand occupational groups associated with achieving net zero carbon emissions by 2050 are those involved in policy and planning, legislation, governance and management, design and implementation, operations and maintenance, education and awareness.

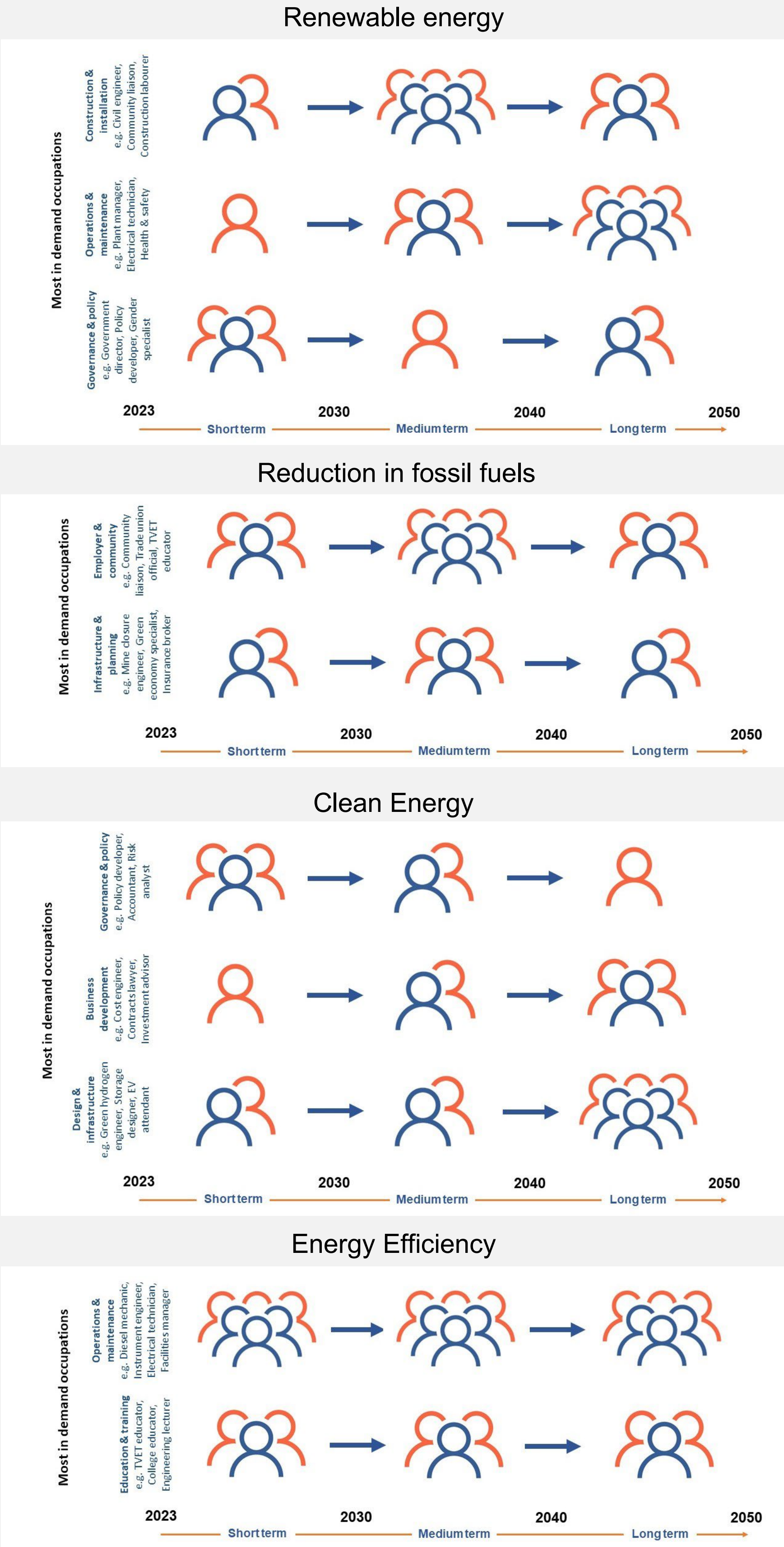
The most recognised shift over time associated with this trend will be a decrease in jobs associated with coal mining and oil and gas in the medium to long term, and the exponential demand in renewable and clean energy jobs from the short term.

The increase in renewable and clean energy jobs are however somewhat different e.g. for renewables there is an expected short term demand of construction and installation associated jobs, which will shift to operations and maintenance in the medium to long term.

In the case of clean energy, and green hydrogen and biofuels the exponential growth in design, construction and operations is likely to be realised in the medium to long term, with short term activities focused on policy and strategy development.

Energy efficiency on the other hand mirrors the occupation demands of the energy insecurity trend, in the sense that much emphasis is placed on operations and maintenance, as well as education and training of the individuals entering these roles.

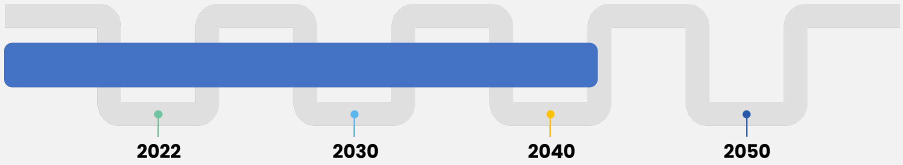
Given that South Africa is an energy intensive country, these occupations will be in both high demand and require large numbers to ensure consistent and effective maintenance and repair throughout the short, medium and long term.



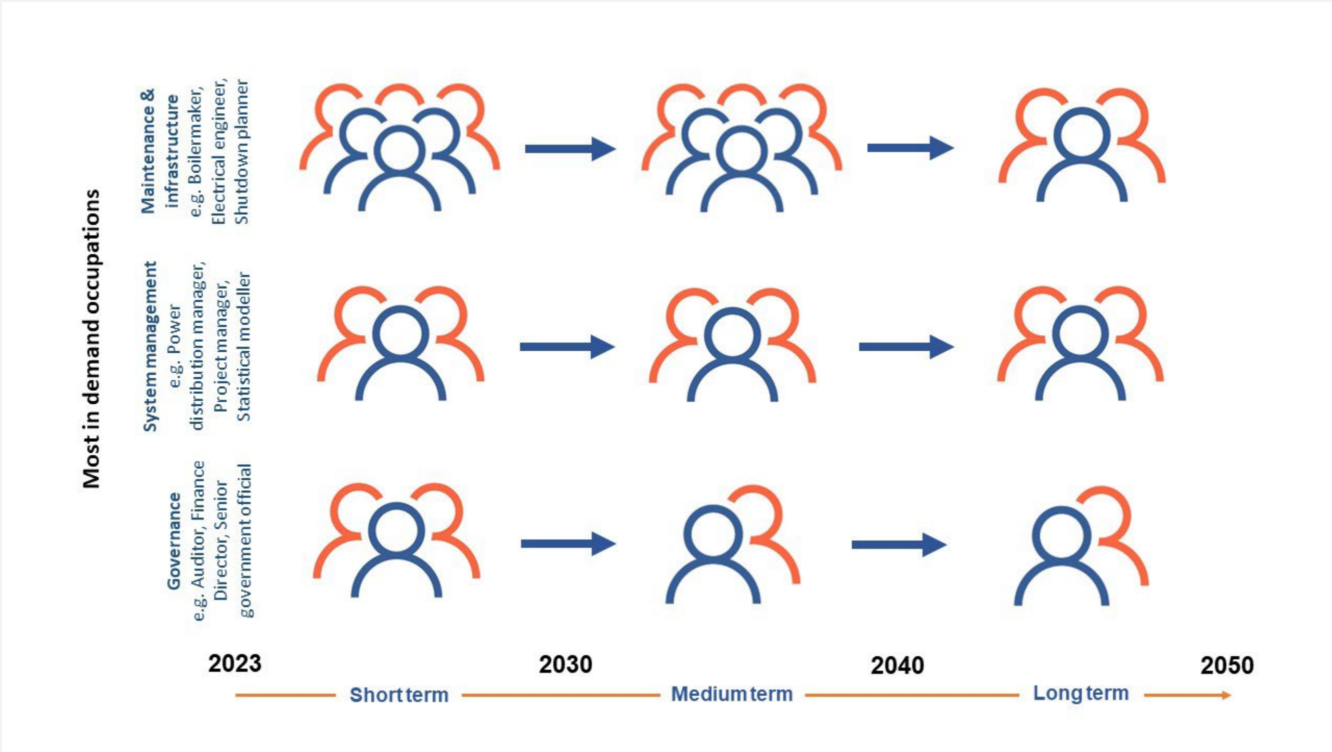
Source: Author derived.

Figure 19: Most in demand occupations for climate change – achieving net-zero

Table 15: Impact of climate change – resilience on the world of work, occupations and skills

Trend: Climate Change: Resilient and adaptable energy systems	
Time horizon	
Impact on the world of work	• Climate change and environmental degradation pose economic growth and employment challenges, and risks will become more significant in the medium- to long-term. However, if appropriately managed and mitigations are put in place, climate change and the associated impacts can create new work opportunities, and secure current jobs (EESI, 2021; ILO, 2023). • Occupations in the energy sector will be required to develop and implement disaster risk and adaptation strategies and interventions, including integration into current plans. This includes review of current infrastructure, risk management, strategic thinking and problem solving, forecasting and modelling, and actuarial analysis at all levels of government. • Current and future infrastructure plans (including smart cities, urban design and spatial planning) will require individuals to adequately review plans to ensure infrastructure is resilient and can withstand climatic shocks e.g. droughts and floods. • To ensure adequate buy-in to mitigation strategies and interventions, personnel and stakeholder awareness will be critical, and requires education practitioners to undertake this role. • In addition to the above a core component of resilience will be a shift towards more renewables and adopting energy efficiency practices (see the climate change: Achieving net zero carbon emissions by 2050 trend above).
Minor occupation groups	• Managing Directors and Chief Executives • Physical and Earth Science Professionals • Mathematicians, Actuaries and Statisticians • Life Science Professionals • Engineering Professionals • Architects, Planners, Surveyors and Designers • University and Higher Education Teachers • Finance Professionals

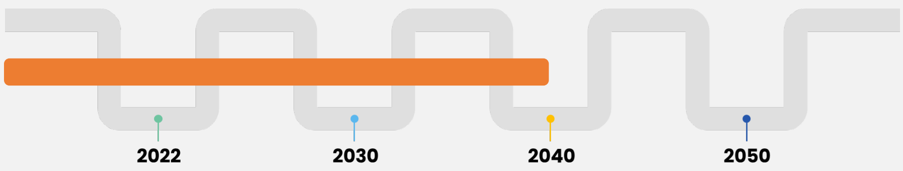
The most in demand occupational groups associated with this trend are those involved in policy and planning, and education and awareness. In comparison to the other trends, it is unlikely that large numbers of individuals will be in demand to fulfil the activities to adapt the energy sector to one that is climate resilient. However, for those involved, these are most likely to be of a high-skill level, such as climate and environmental scientists and advisors, and urban and regional planners. These occupations will be in higher demand in the short term as the government and the sector responds to climate change mitigation targets. In the medium and long term, these occupations will continue to be in demand, however they are more likely to be involved in monitoring and reporting, updating strategy and implementing policy. This trend will also require the skills and knowledge of climate change and environmental educators to raise awareness around climate change and its impacts on the energy system, and associated mitigation interventions. This will be crucial for considered government and industrial sector policy.



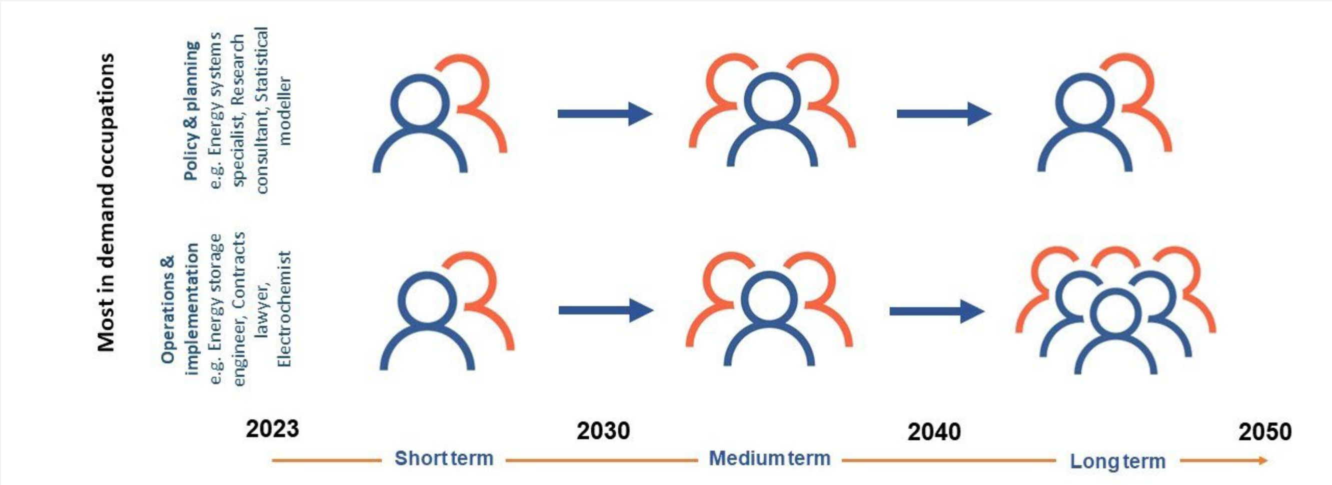
Source: Author derived.

Figure 20: Most in demand occupations for climate change – resilience

Table 16: Impact of shifting towards sector coupling on the world of work, occupations and skills

Trend: Shifting towards sector coupling	
Time horizon	
Impact on the world of work	• The electrification of the economy will have a significant impact on jobs, as new technologies, innovative industrial processes and rules are rolled out and energy-consuming sectors e.g., buildings, transport and industry become interconnected with the energy sector. Initially the impact will be felt in the electricity sector, due to the expansion of renewables, but will shift into the other sectors as renewables and clean energy interventions are adopted by energy consuming sectors (Appunn, 2018; IRENA, 2022a). Also see the climate change: Achieving net zero carbon emissions by 2050 trend above (renewable energy and clean energy [electric vehicles, green hydrogen]) above, and automation and digitalisation trend below.
Minor occupation groups	• Legislators and Senior Officials • Manufacturing, Mining, Construction and Distribution Managers • Professional Services Managers • Engineering Professionals • Electrotechnology Engineers • Finance Professionals • Sales, Marketing and Development Managers

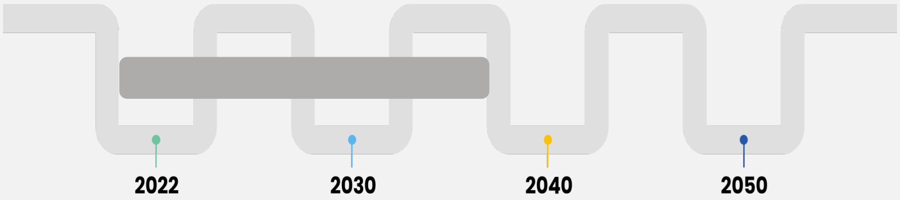
The most in demand occupational groups associated with this trend are those involved in policy and planning, and operations and implementation. Initial occupational emphasis will be placed in policy and planning, as the energy sector becomes more integrated – through the electrification of the economy – into other sectors, such as transportation and agriculture. This will require policy and planning integration to assess the implications and requirements of a more integrated, electrified economy. Over the medium and long term, this emphasis will switch to local manufacturing opportunities and associated occupations involved in implementing the electrification of the economy, with emphasis on e.g., enhanced storage, electric vehicles, and electronics. As the economy becomes more electrified, the more in demand operational and maintenance-related jobs will become.



Source: Author derived.

Figure 21: Most in demand occupations for sector coupling

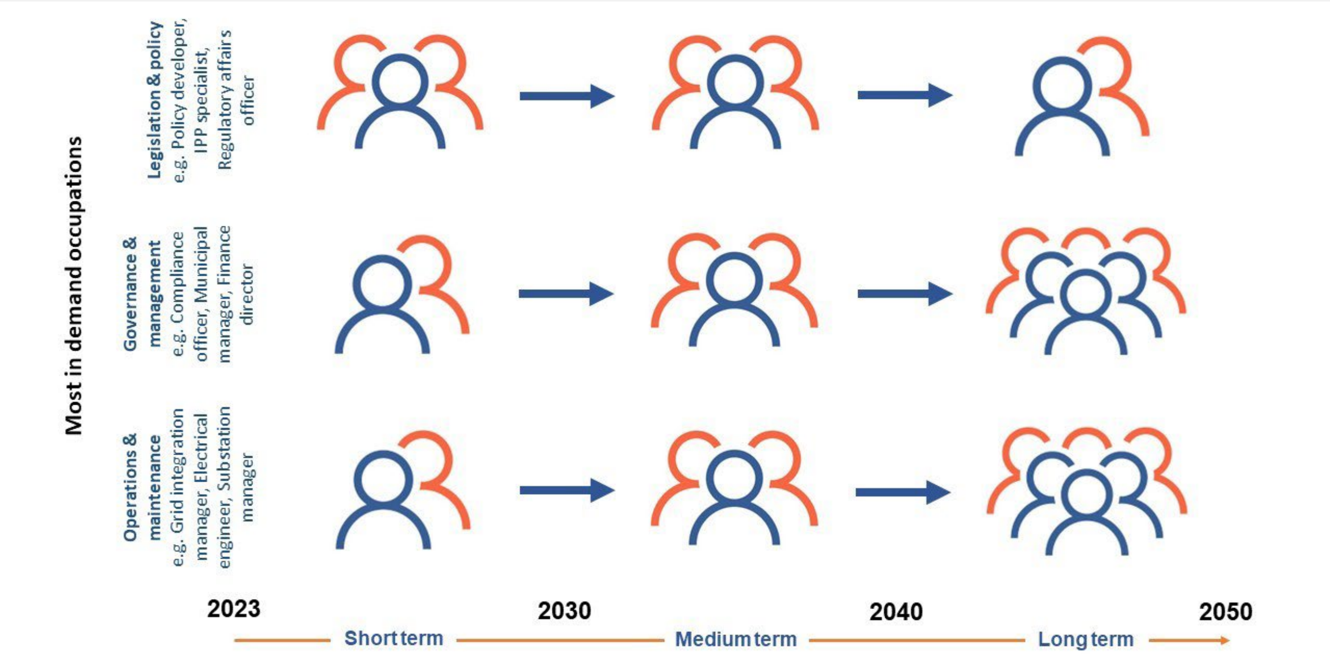
Table 17: Impact of Evolving energy markets on the world of work, occupations and skills

Trend: Evolving energy markets	
Time horizon	
Impact on the world of work	• An expansion in renewables will require a shift in the market to one that is more decentralised and privatisation of activities (DMRE, 2022a). With a shift towards more privatisation and decentralisation, more responsibility will fall on local governments to procure, negotiate and set tariffs, trade and manage the electricity generated within their jurisdictions. Electricity may be generated by the municipalities themselves, Independent Power Producers (IPPs) or cooperatives. • Support will be required to build local government, IPPs and cooperative capabilities to generate, procure and deliver electricity. In the case of local governments, this will require adequate leadership, governance, strategic direction, management and coordination of projects and technical knowledge and skills (SA Government, 2022). • Cooperatives provide an opportunity to create local employment, especially in rural areas, through not only electricity generation, but also through service provision. Therefore, awareness of such opportunities needs to be made known, and they require the collective capabilities to respond to the localised demand (ILO, 2013).
Minor occupation groups	• Legislators and Senior Officials • Managing Directors and Chief Executives • Business Services and Administration Managers • Sales, Marketing and Development Managers • Retail and Wholesale Trade Managers • Engineering Professionals • Electrotechnology Engineers • Vocational Education Teachers • Finance Professionals • Administration Professionals • Sales, Marketing and Public Relations Professionals • Database and Network Professionals • Legal Professionals • Sales and Purchasing Agents and Brokers • Regulatory Government Associate Professionals • Client Information Workers • Numerical Clerks

The most in demand occupational and skills groups associated with this trend are those involved in legislation and policy, governance and management, and operations and maintenance.

With the demand for increased energy security and a growing shift to renewables, emphasis will be placed on implementing decentralised models of energy generation, transmission and distribution.

As such, provincial and local municipalities will be undertaking the roles previously the sole domain of Eskom, this will include e.g., electricity trading, substation management, mini-grid planning, design and maintenance, grid integration, and customer sales. Initial emphasis, however, will be placed on policy, strategy and design, which will also require regulatory expertise. In the mid- to long term emphasis will shift to implementing the decentralised model, increasing local capacity to fulfil the varied activities and maintaining mini- grids.



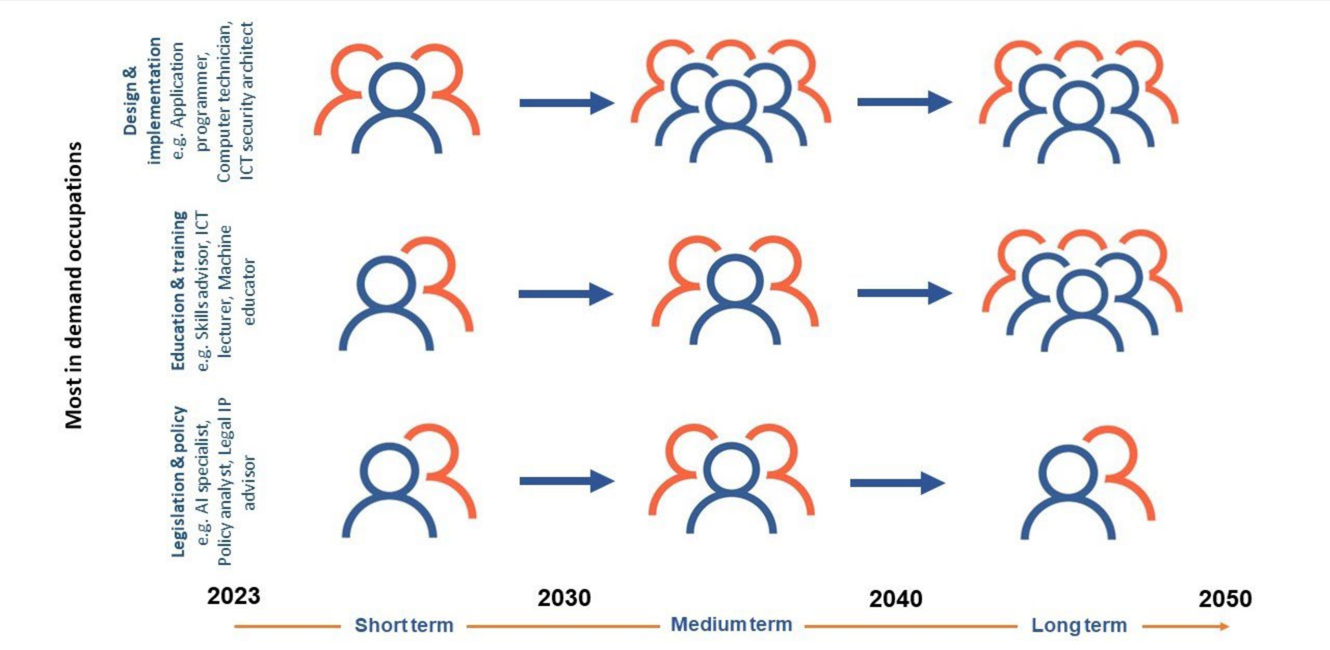
Source: Author derived.

Figure 22: Most in demand occupations for evolving energy markets

Table 18: Impact of automation and digitalisation on the world of work, occupations and skills

Trend: Automation and digitalisation	
Time Horizon	
Impact on the world of work	• Automation, digitalisation and technological changes will significantly impact and disrupt jobs through the need for new work systems, processes and procedures. This will result in the creation of new jobs, job displacement or the need to adapt current jobs to adopt digital and automation technologies. This in turn will require extensive and continuous upskilling, reskilling and retraining (Chui, Lund and Gumbel, 2018; EWSETA, 2021; IEA, 2017; Torkington, 2023). ○ Examples of job displacement include those involved in routine, predictable and repetitive tasks, unsafe work environments or where automation replaces humans e.g. truck drivers replaced by fully autonomous cars and trucks (Careers in Energy, 2023; IEA, 2017). • Policy developers in the energy and coupled sectors should participate in broader government and industry discourse to prepare and manage the sectors for a digital transition (IEA, 2017). • The implementation of a digital infrastructure will require specialist ICT skills (high levels of specific digital skills are needed), such as coding and cybersecurity, while across the sector all employees will require generic ICT skills for more basic or broad tasks and to operate digital and automation technologies and machinery e.g. use of automation and digital devices and sensors to diagnose issues and optimise electricity generation operations (AISC, 2022; AIS, 2019; IEA, 2017). • It is imperative that labour market, demographic, and skills supply and demand assessments are undertaken within the energy and related sectors to temper job loss fears, and to identify sector specific opportunities. Otherwise job losses and skills gaps will begin to arise as the evolution of technology outpaces the number of individuals trained, this could be exacerbated by education curricula being dated, and youth (who do not have access to computers) not developing digital skills (DHET, 2022; IEA, 2017). • An increase in digitalisation can impact skills supply, with e-learning becoming more prominent. As such, the sector and/or associated education and training providers will need to invest in upskilling educators and digital infrastructure (EWSETA, 2021).
Minor occupation groups	• Legislators and Senior Officials • Managing Directors and Chief Executives • Manufacturing, Mining, Construction and Distribution Managers • Information and Communications Technology Service Managers • Engineering Professionals • Electrotechnology Engineers • Architects, Planners, Surveyors and Designers • University and Higher Education Teachers • Vocational Education Teachers • Software and Applications Developers and Analysts • Database and Network Professionals • Physical and Engineering Science Technicians • Process Control Technicians • Information/Communications Technology Operations and User Support Technicians • Machinery Mechanics and Repairers • Electrical Equipment Installers and Repairers • Electronics and Telecommunications Installers and Repairers

The most in demand occupational groups associated with this trend are those involved in design and implementation, legislation and policy and education and training. As indicated automation and digitalisation will have a significant impact on all jobs in the sector. While this may lead to a decrease in jobs associated with menial and repetitive tasks over the short and medium term, it is clear that all employees will require upskilling, and new jobs will emerge in a rapidly changing technical world. As all jobs will require some form of upskilling and IT training throughout their careers much emphasis will be placed on not only educating ICT of the future, but also those in the work place. As the sector becomes more automated and digitised, the demand for educators and trainers, especially in the workplace will grow significantly over the medium and long term. In the case of design and implementation new jobs are already emerging, however new (and in some cases yet unknown) jobs will increase exponentially over the mid- to long term, in particular those involved in automation and robotics. Current in demand occupations, such as application and software developers, data analysts and scientists, ICT programme managers and network architects are expected to increase in demand over the mid- and long term, especially as the electrification of the sector becomes more prevalent.



Source: Author derived.

Figure 23: Most in demand occupations for automation and digitalisation

Key Occupations

Drawing on the impact of the trends on the world of work, the following Top 10 occupations emerged as key to maintaining, enhancing and transitioning the sector across generation, distribution, transmission and consumption:

- Electrical Engineer
- Policy Consultant / Officer / Planner
- Power Distribution Engineer
- Energy Specialist
- Programme or Project Manager
- Electrical Engineering Technician
- Environmental Scientist
- Statistical Modeller
- Maintenance Technologist
- Process Design Engineer

The figure below illustrates these top 10 occupations within the context of other most commonly cited occupations in demand. It is interesting to note that while traditional energy engineering and technician jobs are cited, there is much demand for operational, management, finance, legal, environmental and social jobs.

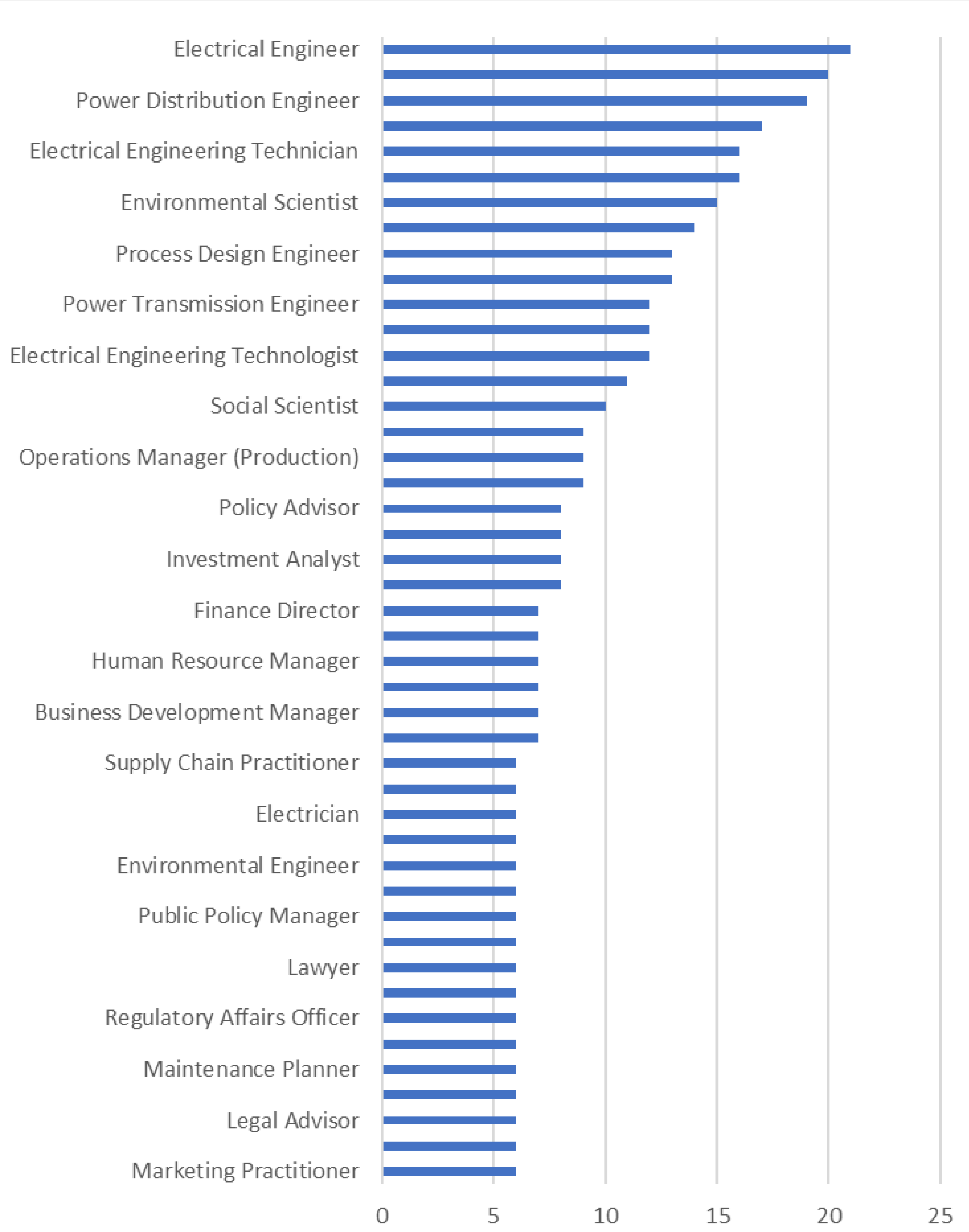


Figure 24: The most commonly cited occupations in demand

Occupation demand across the trends illustrates different occupations are required to mitigate or respond to the trends, for example environmental scientists are important to deliver a low carbon energy sector, and a resilient and adaptive energy system. There are, however, occupations that are transversal and required across all trends, notably policy professionals, energy specialists and programme or project managers. The figure below illustrates how the top 10 most in demand occupations are distributed across the trends.

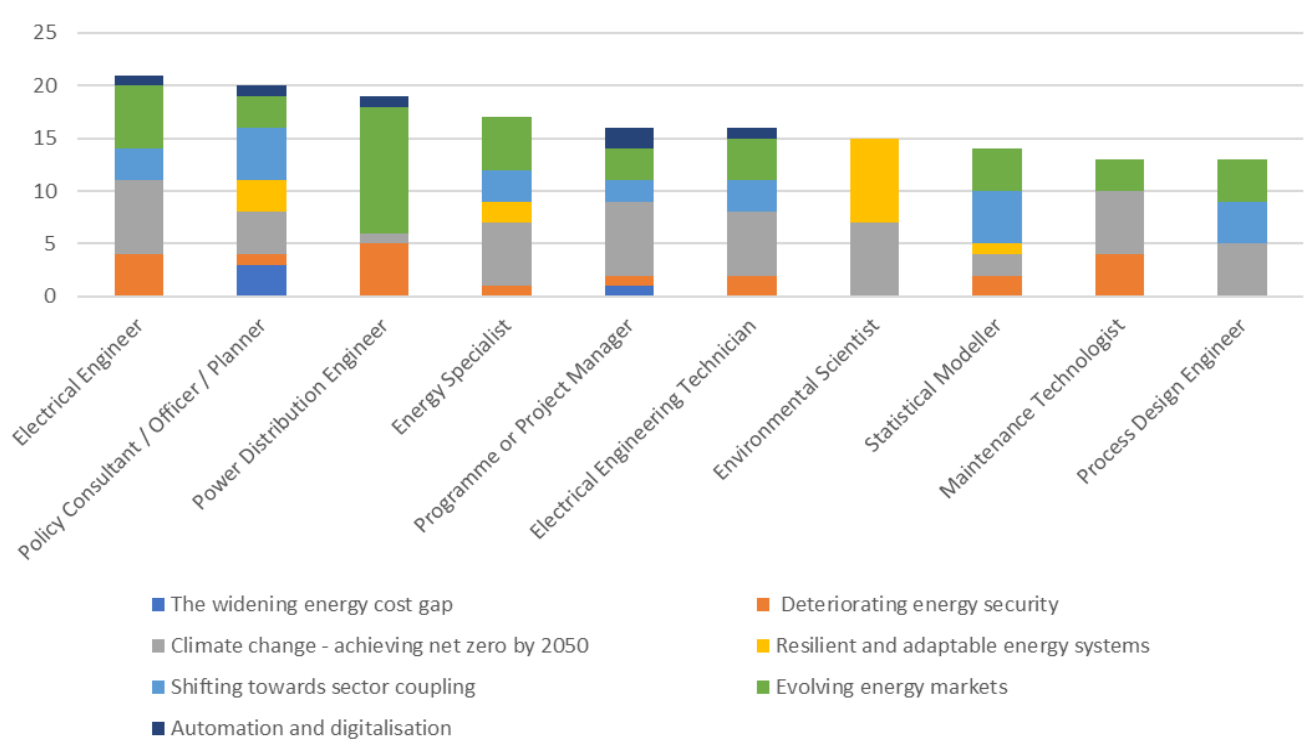


Figure 25: Top 10 most in demand occupations, by trend

Of occupations identified, those listed in the Table below are deemed critical for South Africa's economic reconstruction and recovery plan (DHET, 2022, 2022a), and therefore require intervention to ensure the energy system is resilient and can effectively transition in a just and sustainable manner.

Those highlighted in red are recognised as being the Top 10 hard-to-fill occupations by the Energy and Water Sector Education and Training Authority (EWSETA).

This list also correlates with recent research undertaken by Michael Page Africa, a recruitment agency, which listed the most in-demand jobs and skills in South Africa. Their findings are set within the context of these jobs also being in international demand, resulting in global companies poaching South Africans with this experience (Ebrahim, 2022). Therefore, retention of these skills is critical to sustaining and fulfilling the transition of South Africa's energy sector.

Table 19: Energy sector transition occupations listed as critical

• Actuary • Agricultural Engineer / Technician • Air-conditioning & Refrigeration Mechanic • Applications Programmer • Biotechnologist • Business Development Officer • Chemical Engineer / Technician • Chemist / Chemistry Technician • Civil Engineer / Technician • Climate Change Scientist • Computer Network & Systems Engineer • Construction Project Manager • Corporate General Manager • Customer Service Manager • Data Management Manager • Data Scientist • Draughtsperson • Economist • Electrical Engineer / Engineering Technician • Electrical Equipment Mechanic • Electronic Engineer / Technician • Energy Engineer / Technician • Engineering Manager • Environmental Manager / Scientist • Geologist • Geophysicist • Forensic Accountant • Information & Communication Technology (ICT) Systems Analyst • ICT Security Specialist • Industrial Designer • Industrial Engineer / Technician • Instrument Mechanician • Integrated Manufacturing	• Line Process Control Technician • Investment Advisor / Analyst / Manager • Lift Mechanic • Manufacturing Operations Manager • Manufacting Technician • Market Research Analyst • Mechanical Engineer / Technician • Mechatronics Technician • Meteorologist • Metallurgist • Microbiologist • Millwright • Mineralogist • Mining Engineer • Organisational Risk Manager • Physicist • Policy & Planning Analyst / Manager • Product Assembler • Programmer Analyst • Project Manager • Purchasing Officer • Refrigeration Mechanic • Quality [Systems[Controller / Manager (Manufacturing) • Quantity Surveyor • Research & Development (R&D) Manager • Safety Inspector • Software Developer • Solar Photovoltaic (PV) Service Technician • Supply & Distribution Manager • Transportation Electrician • Wind Turbine Power Plant Process Controller

Source: DHET, 2022, 2022a; EWSETA, 2021.

Required and critical skills

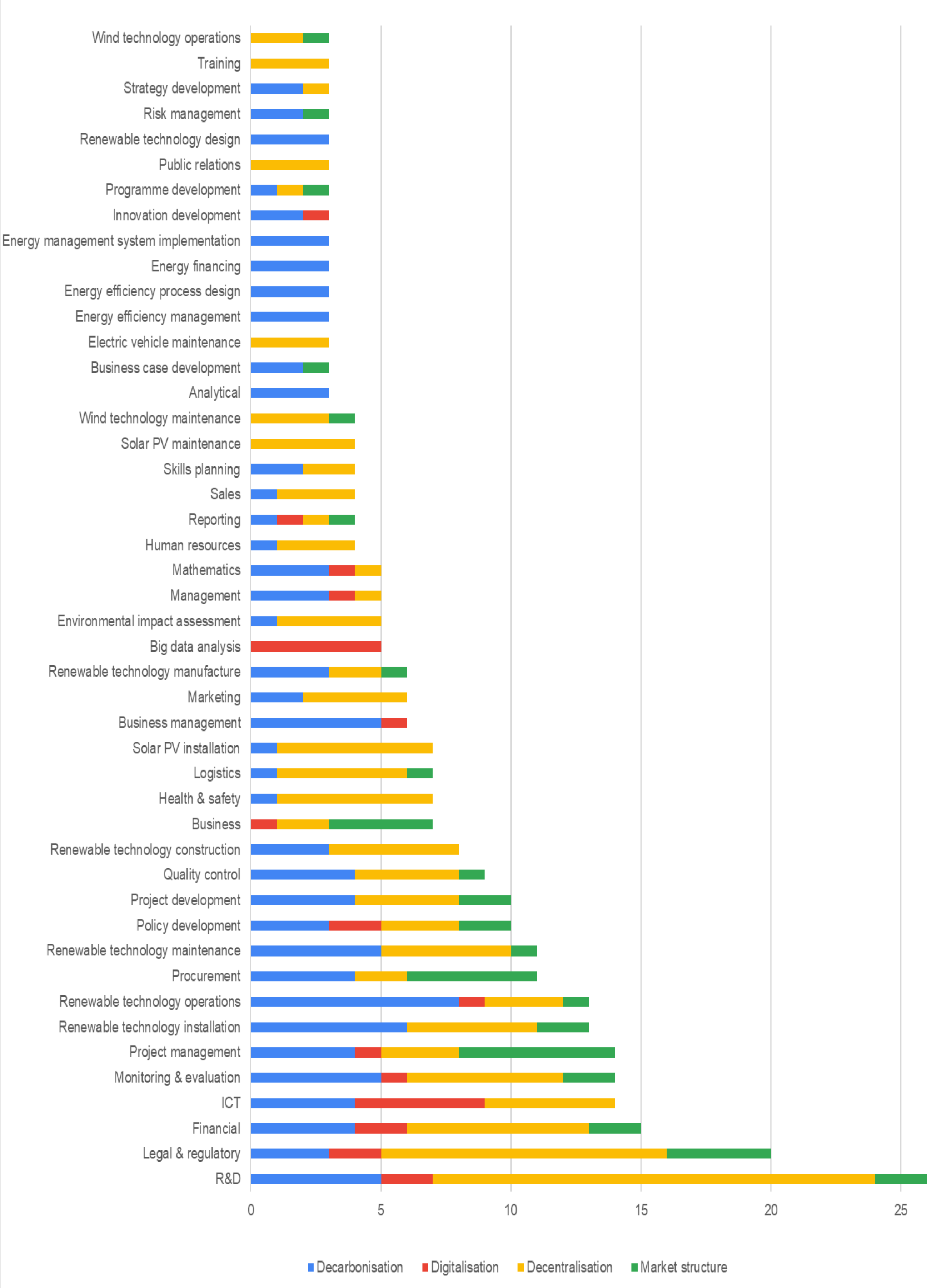
It is also worthwhile acknowledging that the energy sector is a multidisciplinary field; this calls for a complex knowledge and skills base which must realise the importance of management, communication, leadership, environmental and other skills. For example, there is a great demand for skills, from engineering and environmental skills to energy economics.

Drawing on the desktop, research, job advert analysis and workshops the top 10 most commonly cited technical and 'soft' skills cited are detailed in the table below.

Table 20: Top 10 most commonly cited technical and 'soft' skills

Technical skills	'Soft' skills
1. Research & Development (R&D)	1. Project management
2. Legal & Regulatory	2. Leadership
3. Financial	3. Communication
4. ICT	4. Agility
5. Monitoring & Evaluation	5. Emotional Intelligence
6. Renewable Technology Installation	6. Mentoring
7. Renewable Technology Operations	7. Community Outreach
8. Procurement	8. Critical Thinking
9. Renewable Technology Maintenance	9. Decision Making
10. Policy Development	10. Problem Solving

These most commonly cited skills are presented in in the figures below in relation to the broader set of skills, by trend theme.



F

igure 26: Most commonly cited technical skills

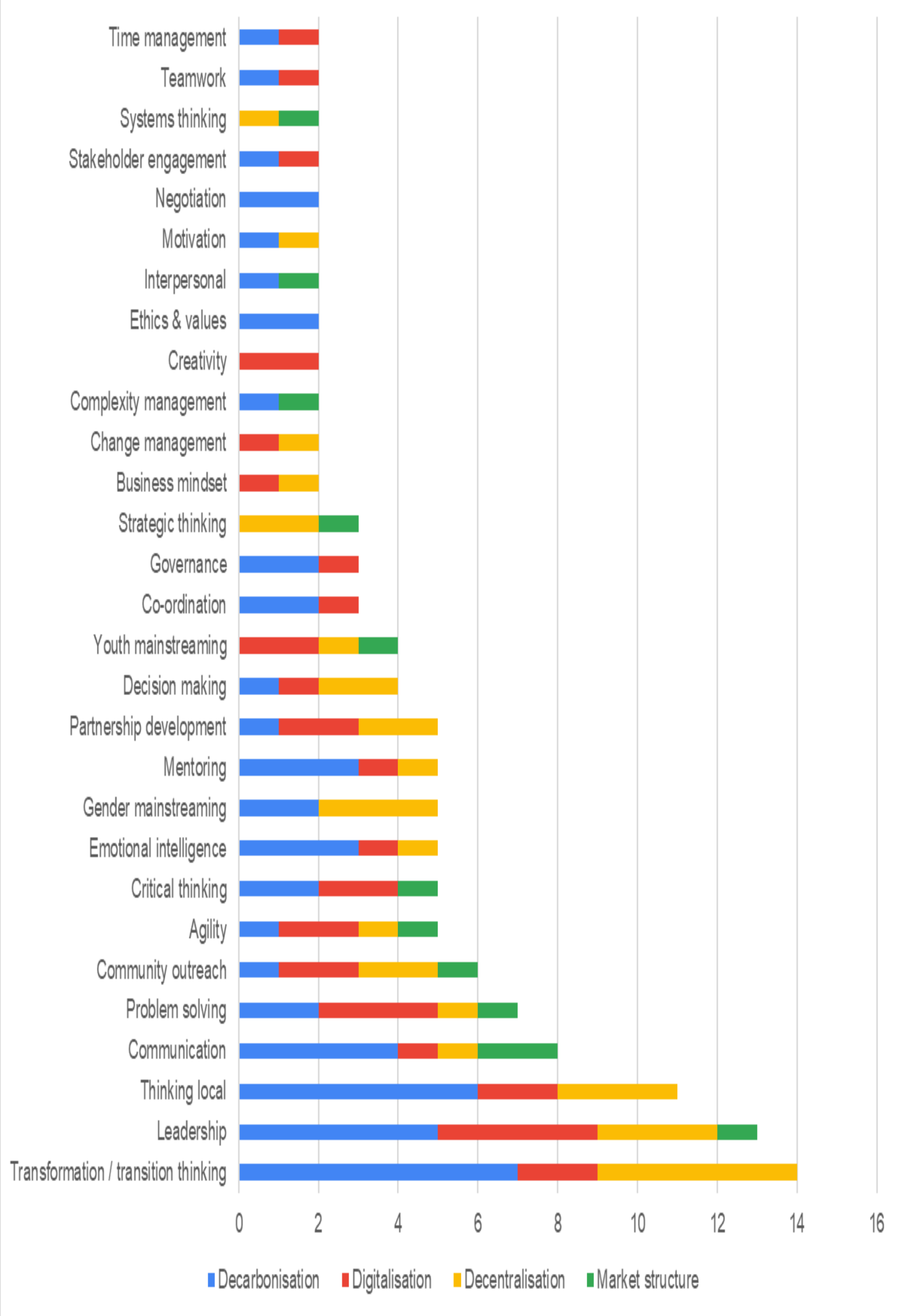


Figure 27: Most commonly cited 'soft' skills

Of the core skills listed, the following are deemed as critical skills gaps by EWSETA (2021):

- Technical (job specific)
- Financial management
- Computer literacy
- Management
- Advanced IT and software
- Leadership
- Occupational health and safety skills
- Project management
- Communication
- Problem-solving.

According to EWSETA (2021), these are skills gaps identified by employers in the energy sector and are therefore critical to resolve to ensure a job or tasks are adequately performed.

Jobs and skills considerations

To determine the core jobs required to transition the sector over the short-, medium- and long-term, the jobs presented above, are also listed as those most likely to be in most demand along the transition time continuum. These are proposed based on likely core activities and task requirements for a particular trend e.g. a high demand for construction-related jobs and skills during the initial stages of ramping up of renewable energy solutions.

While there will be peak pockets of jobs and skills demand, it should also be noted that in most instances a particular job or skill will be required for the full duration of the time horizon. Likely peaks, levelling out and transitioning of jobs along the time horizon need to be recognised e.g.:

- Most significantly **fossil-fuel-related jobs will decrease** between 2023 and 2030. This will have implications for skilling, reskilling, and upskilling. Planning to mitigate these job losses is therefore critical and needs to be very well planned and considered.
- With the shift away from fossil-fuels towards more **renewable and clean energy**, the initial demand for design, construction and installation-related jobs will be high. This will be followed by more operations, maintenance and evaluation jobs to ensure installed infrastructure and the associated system is effectively managed and maintained. Installation, Repair and Maintenance is an important emerging area that has significant implications for local enterprise development and community skills development. The increased demand for renewable and clean energy jobs is likely to require an increase in specialisms at various skill levels, and not necessarily new jobs e.g. specialist green hydrogen or energy storage engineers and technicians (Wits REAL, 2022). Policy and strategy implementation needs to be cognisant of these demands.
- **Policy-related jobs** (including policy development, management and implementation; research and analysis; and topic specialists) are critical short term occupations. In this regard, one of the most important considerations is the need for more integrated policy, and policy implementation. this has implications for skilling, Rosenberg et al 2016, found that the competencies required to drive sustainability in government were clustered as technical, relational and transformational

competencies for: making the case; integrated sustainable development planning; strategic adaptive management and expansive learning; working across organisational units; working across knowledge fields; capacity and organisational development; and principle-based leadership. Policy developers need to be knowledgeable, networked and aware of activities within and associated with the sector to ensure policy is relevant, systems-oriented and conducive to implementation. To achieve the intended goals set out in policy and strategy, it is imperative that there is adequate human and financial resourcing within government to roll out and implement policy.

- **Financial and governance-related jobs** are also critical in the short-term. As the sector begins to transition it requires financial support and investment to do so. Upskilling and reskilling of current finance employees with sustainability knowledge and the business case for a just transition of the energy sector. To this end, the ethical governance of expenditure and investment is core, and requires individuals with an ethical mindset, and a public and private sector that is capable of and accountable to delivery.
- Decentralisation of the energy system will significantly impact the **district and local municipal workforce.** Activities, once the domain of Eskom, will become the responsibilities of local governments e.g. energy planning, integration, distribution, trade and maintenance. The upskilling of the current workforce and employment of more energy-related staff will be critical. This will require human resource practitioners within the local government to be knowledgeable of these new job demands and associated skills requirements.
- As indicated previously, a transformative energy sector requires the acknowledgement of a broader set of jobs and skills beyond the techno-economic. The role of **social scientists** (e.g. anthropologists, sociologists, gender specialists, community development co-ordinators, environmental education and inclusivity specialists, social workers, and trade union officials) will grow over time, with initial emphasis on dealing with affected communities, whether due to mine closures or the citing of new renewable and clean energy facilities.
- Given the need for the upskilling and reskilling of the current workforce, or the production of new graduates into areas of growing job demand, there is a critical need for suitably knowledgeable and capable **post-school educators** (university, TVET and community college, and work based educators). This is discussed in more detail in the following section.

Skills planning and anticipation is critical early on in discussions - not as an add on at the end of technical, policy or strategy development. Skills planning should:

- Consider the long-term employment impact of the transition, which depends on the scenarios, power mix assumptions, development models and scaling assumptions (site, technology, energy sub-sector) (Meridian Economics, 2018). This also includes acknowledging issues of uncertainty and probability (including scenarios).
- Recognise jobs and skills along the expanded, broader value chain and time horizon.
- Be cognisant of streams of work and connected f jobs required at certain points and activities along the time horizon e.g. construction, policy development and automation.
- Acknowledge the geographical impact and required jobs especially given many of the impacts of mine closures and renewable technologies are and will be in rural areas. This will require the need to seek alternative work for those who lose their jobs, or to develop local capacity to support

new activities. This will require the training and upskilling of local communities to support new opportunities (Wits REAL, 2022).

- Discussion and decision-making should include different actors groups - government (national, provincial and local), industry and business (large and small, commercial and informal), academia and research, and civil society (e.g. NGOs).
- Requires transparent disclosure of employment numbers by different actor groups, using standardised employment metrics and categorisation methods (Meridian Economics, 2018). Job numbers should be cognisant of trade-offs and the realities of the wider renewable and clean energy job demand.

IMPLICATIONS ON THE SOUTH AFRICAN SKILLS SYSTEM

Introduction and purpose

This section provides an overview of the current energy-related courses offered in South Africa, and reviews these against the jobs and skills required to transition the sector. The purpose of this is to establish whether the education system is able to adequately support the provisioning of skills (supply) for the sector's transition, and where gaps exist, or adaptations may be required.

Current energy-related skills provisioning in South Africa

This section provides an overview of the courses identified by level of qualification. Just over 1,000 courses were identified. These capture courses provided by recognised public and private universities and colleges, and popular private training providers. It should be noted that while the search was extensive, such an exercise will not be able to identify all courses offered. Those not captured are likely to be short courses offered by private or civil society organisations. The Top 10 most commonly offered energy-related courses are:

1. Electrical / Electronic [Engineering]
2. Mechanical Engineering
3. Chemistry
4. Engineering Studies [and Related Design]
5. Chemical Engineering
6. Electrical Infrastructure Construction
7. Environmental [and Geographical Science]
8. Science and/or Technology Education
9. Biotechnology
10. Biochemistry

This suggests that traditional engineering and science-related disciplines are well represented across PSET, with a range of qualification levels offered for these. The Figure below illustrates the diversity of courses offered, with a focus on courses with more than five offerings across the PSET system, by qualification level. For a detailed list of energy-related courses offered in South Africa see Appendix 2.

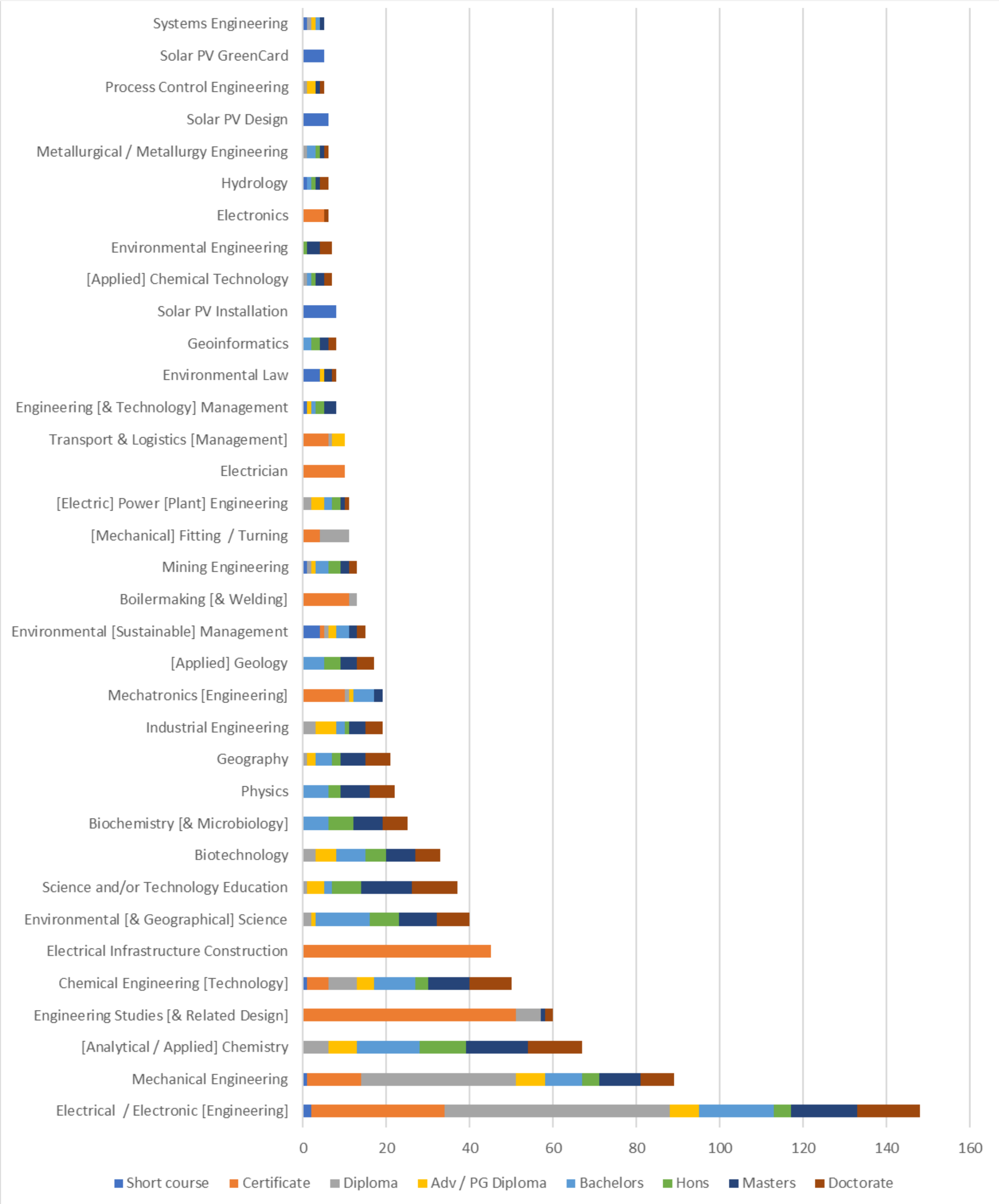


Figure 28: Current energy-related courses with more than five offerings across the post-school education and training system (PSET), by qualification level

Regarding Electrical / Electronic [Engineering] the most prominent level of qualification is at the Diploma and Certificate level (offered by TVET colleges and Universities of Technology). It is also well represented at under- and postgraduate level across Traditional Universities and Universities of Technology.

It can also be noted, that with the shift in emphasis and need to supply the growing renewables energy sector with appropriate skills and knowledge these institutions are beginning to offer short specialist courses on the topic. For example, Stellenbosch University's Centre for Renewable and Sustainable Energy (CRSE) offers a variety of short courses on wind, storage and energy systems. The University of Pretoria's Centre for New Energy Systems, on the other hand, focuses its short courses on energy market operation, management and optimisation.

Universities of technology, as would be expected, have picked up the baton to deliver renewable energy technology skills needs with, for example, the Durban University of Technology (DUT) and the South African Renewable Energy Technology Centre (SARATEC) at the Cape Peninsula University of Technology (CPUT), offering a number of renewable energy technology installation and technical courses for wind, solar and grid connection.

Most of the country's TVET colleges focus on traditional electrical engineering, installation and infrastructure certificates, with few placing explicit emphasis on renewable energy or energy efficiency. Very few, if any, appropriate courses are offered by community colleges.

A review of the course offerings also suggests the growing emergence of short courses. This is being driven by current employer demand and the deteriorating energy sector demand. Courses vary, and range from energy auditing, planning and management, to financing of energy projects, electrical engineering and renewable technologies design, installation and maintenance (wind and solar).

Given the current energy insecurity issues, there is increasing demand for solar design and installation skills, and the skills system is responding to this through the provisioning of solar PV short and accreditation courses. Another example of the short course offering responding to the future energy sector is that of green hydrogen and renewables, with many introductory courses on these topics identified.

Alignment of current skills provisioning with trends and the energy transition

In reviewing the courses offered versus sector and transition demand (in relation to the trends) it is possible to determine where skills provisioning is well covered, and where gaps exist, per trend:

Table 21: Impact of the trends on skills provisioning

<table>
<tr><th colspan="2">Trend: The widening energy cost gap</th></tr>
<tr><td>Core areas of occupation demand</td><td>Gaps</td></tr>
<tr><td>• Legislation and regulation
• Leadership and management
• Forecasting and modelling
• Financial
• Community / user liaison
• Sales and marketing</td><td>• Specialisation in energy-related legislation and regulation, financials, forecasting and modelling and sales and marketing.
• Inadequate supply of energy-related leadership, energy integration and management courses, especially at university level.</td></tr>
<tr><th colspan="2">Trend: Deteriorating energy security</th></tr>
<tr><td>Core areas of occupation demand</td><td>Gaps</td></tr>
<tr><td>• Legislation and regulation
• Leadership and management (incl. good governance)
• Mathematics and statistics
• Electrical and process engineering and associated technical
• Financial and investment
• Sales
• Maintenance and repair
• Security</td><td>• While courses on public sector management and governance exist, access and uptake need to be encouraged and increased.
• Inadequate supply of maintenance, repair and non-electrical technical (e.g. mechanical, boilermaker) courses at TVET and community colleges.</td></tr>
<tr><th colspan="2">Trend: Climate change: Achieving net zero carbon emissions by 2050</th></tr>
<tr><td>Core areas of occupation demand</td><td>Gaps</td></tr>
<tr><td>• Legislation and regulation
• Leadership and management (incl. good governance)
• Forecasting and modelling
• Business development
• Sales and marketing
• Policy development and implementation
• Manufacturing, mining, construction and distribution management and labour
• Environmental and climatic science and research
• Electrical / electronic, mechanical, civil, process and design engineering and associated technical
• Site planning and surveying
• Science / technology, engineering, environmental and social education
• Financial and investment
• Community and stakeholder liaison / research
• Maintenance and repair
• Engineering education</td><td>• Engineering and technical specialisms (renewables [solar, wind, bio] and clean energy [green hydrogen]) are lacking at all levels of education, especially in key affected geographical areas.
• While sales and marketing, management, financial and investment, and policy development courses exist, there is a need to provide renewable and clean energy specific courses and curricula.
• Life and entrepreneurial skills for affected local communities.
• Short courses to upskill and reskill current employees to adapt to changing and new knowledge areas e.g., renewables, green hydrogen, climate change impacts (introduction, opportunities and considerations).
• Post-school engineering-related educator courses / upskilling.</td></tr>
</table>

Trend: Climate Change: Resilient and adaptable energy systems	
Core areas of occupation demand	Gaps
• Leadership and management • Forecasting and modelling • Urban and rural planning • Environmental and climate science • Environmental and social impact • Finance and investment • Engineering, physical and social science education	• More specific climate science / energy nexus higher level courses. • Leadership and management knowledge upskilling on climate impact on the sector. • Climate finance (higher level and short courses). • Higher-level climate / engineering science educator courses.
Trend: Shifting towards sector coupling	
Core areas of occupation demand	Gaps
• Legislation and regulation • Leadership and management (incl. good governance) • Policy development • Manufacturing, mining, construction and distribution management (electrification) • Forecasting and modelling • Electrical and process engineering and associated technical • Financial and investment • Sales and marketing • Maintenance and repair • Electric vehicle and green hydrogen	• Higher-level specialisms in electric vehicles, green hydrogen, integrated energy systems. • Upskilling of leadership, management, sales and marketing, and policy developers on sector coupling implications and opportunities.
Trend: Evolving energy markets	
Core areas of occupation demand	Gaps
• Government legislation and regulation • Local public sector leadership and management (incl. good governance) • Business administration • Financials and investment (incl. trade) • Sales • Public relations • Public sector educators • Client Information Workers	• Upskilling of local government leadership and management on energy provision and good governance. • Upskilling of human resource professionals on energy-sector job requirements to employ an increased number of local government energy jobs. Also see the widening energy cost gap and deteriorating energy security trend education gaps above.

Trend: Automation and digitalisation	
Core areas of occupation demand	Gaps
• Legislation and regulation • Leadership and management • Information and technology management and operation • Software and application development • ICT engineering and associated technical • ICT data management and analysis • Digital sales and marketing • Data and network security • Automation and robotics • Electrical and automated machinery installation and maintenance • ICT, automation and robotics educators	• Automation and robotics engineering at university and TVET level. • Accredited ICT and automated machine installation and repair. • Short courses for leadership, management and policy developers on impact of digitalisation and automation on the sector.

Required considerations for energy skills provisioning

The presentation of provisioning gaps above provides an indication of the main gaps between occupational demand and education supply. This suggests that the PSET system needs to consider responding to the sector's transition demand as follows:

- Offering specialist degree courses at undergraduate and postgraduate levels (currently specialisms are offered at postgraduate level). Specialisms would include renewables (solar, wind, biomass), clean energy (electric automotive, green hydrogen), and automation and robotics. These specialisms can be determined in consultation with employers and sector specialists and advisors.
    - This includes updating and adapting current e.g. engineering, physical and social science, business science and administration, public sector management, and law courses and curricula to cover topics such as renewables, clean energy, energy efficiency and climate change.
- Increasing the number of energy-system specific technology maintenance and repair courses at TVET and community colleges.
- Upskilling leadership and management (public and private), policy developers, sales and marketing professionals, and educators on specific topics (e.g. sector coupling, climate change impacts, energy markets).
- More broadly, short courses on e.g. computer literacy, organisation and project management [incl. good governance], finance management, client and stakeholder communication and engagement should be offered to the sector.
- Ensure there is adequate supply of good PSET educator courses (university lecturing, TVET and community college teachers) in engineering (e.g. electrical / electronic, automation and robotics, civil, mechanical, bio/chemical), climate change environmental science, public sector management, policy development and delivery.

- Considered planning of what is offered locally by TVET and community colleges to support local communities to adapt to the transition e.g. e.g. away from coal, or to respond to new employment opportunities e.g. solar in the Northern Cape.

While the focus above has been on PSET, one of the major challenges facing energy skills supply in South Africa is the matric pass rate i.e. the number of individuals who can enter the PSET system. Therefore, while there may be adequate skills provisioning for e.g. electrical engineering and associated technical professions, if the number of individuals enrolling and graduating from these courses is low, this impacts on the availability of adequately educated and skilled individuals to fulfil demand. While this report does not provide a detailed assessment of graduates per course, it is worth noting that an estimated only 45% of those who start school in South Africa matriculated (Cloete, 2022). Of those that wrote the National Senior Certificate (matriculated) in 2021, 36% achieved a bachelors pass i.e. could enter university (O'Regan, 2022). This suggests that the pipeline for individuals to fulfil the sector's transition and future demand is pressured. Not only does this indicate not enough learners are able to enter relevant fields and levels of study, but for those that do graduate, they will be in demand across all sectors of the economy. This being especially the case for those with transferable knowledge and skills e.g. accounting, business studies, economics, geography, life and social sciences, mathematical literacy, mathematics and physical science and ICT.

Given the poor basic education pipeline, it is therefore highly recommended that both national government and the broader energy private sector places emphasis and invests in improving the provisioning of basic education (e.g. infrastructure and teacher quality), and the matric pass rate to ensure the adequate supply of good quality learners into the PSET system.

CONCLUSIONS

Taking into consideration all the findings and analysis conducted in this research, a set of conclusions were identified to help guide future work. These conclusions are detailed below

Uncertainty and trends

- The energy sector is being driven by a number of key trends both global and local. These have critical implications for skills development as not only will current jobs be impacted, but new occupations and skills will be needed.
- Skills requirements for the energy system necessitates an ecosystem approach and acknowledge the transformative process that is occurring over time and local geographic areas. Siloed approaches need to therefore be avoided to maximise any opportunities and build any trade-offs into decision making.
- The energy sector is in crisis and faces a great deal of uncertainty in developing a skills roadmap as a result. This means that flexibility and contingencies need to be built into any skills roadmap as well as continual tracking of the environment as uncertainties unfold.

Occupations and skills

- The shift to decarbonisation and electrification is being reflected in the increased demand for a wider variety of jobs, including outside the energy sector. This has resulted in the emphasis on only techno economic jobs shifting to a socio-economic and just transition emphasis.

- The private sector is employing specialists in future areas such as green hydrogen in order to be able to develop policy and drive the trajectory. The public sector is focused more on current jobs.
- The decentralisation and automation/AI trends are resulting in a shift in the types and location of jobs from more technical to more construction jobs for example in renewables.
- The emerging energy markets are driving new types of jobs but also where they are located geographically and sectorally, e.g. from a central utility to a municipality etc.

Impact on the education sector

- There is adequate education supply for traditional energy jobs at university level (number of courses not number of graduates).
- Traditional energy education is not supplying adequate specialisations e.g. specific renewable technologies or clean energy.
- It is unclear if curriculum and education quality are responding adequately or is appropriate for future demand.
- Community and TVET colleges are not responding to or providing appropriate training for current and future demand e.g. solar in the Northern Cape or job decreases in Mpumalanga.
- The pipeline from basic education is poor and this is impacting the throughput of students in the relevant courses at tertiary education level.

Skills planning

- Skills planning needs to be flexible given the uncertainties and this is currently not considered adequately.
- Skills planning needs to be done with a building an ecosystem (geographical and sectoral) mindset and not once off siloed interventions.
- All sectors need to be included in skills planning for the energy sector to avoid duplication, and to ensure that the enabling jobs in the ecosystem are all adequately provisioned.

CONSIDERATIONS AND RECOMMENDATIONS

Introduction and purpose

This section pulls together all the analysis into a set of critical considerations and recommendations as to the way forward.

Considerations and recommendations

The table below outlines some key recommendations on future work and implementation actions for each consideration identified through this work. This is a critical set of recommendations given the timeframes involved and the need to begin implementation that is tracked and reported on as soon as possible.

Table 22: Summary of considerations and recommendations

Consideration	Recommendation
Uncertainty and trends	• Develop a more detailed set of scenarios and impact on jobs to acknowledge the nuances of each scenario on jobs and locations e.g., Northern Cape etc. • Track uncertainties to feed into flexibility of skills planning.
Multi-dimensional approach to skills development	The roadmap will need to have a coherent vision, concurrently work on following: • Reskilling and upskilling adults to be better equipped to navigate the energy transition at various points in the energy value chain. • Aligning the energy skills development system with the anticipated labour force needs of the future, with particular focus on jobs to support a just energy transition. This involves sophisticated anticipatory skills development and working with labour market intelligence, as well as the strengthening of skills system innovations across the energy value chain and its associated ecosystem i.e. not to be relegated to a narrow band of technical skills only. It also involves investing in skills development capacity and building of new types of skills and specialisms. • Resourcing foundational skills development throughout the education system to improve the adaptive capacity of the broader workforce. This involves curriculum transformation, teacher capacity development in the schooling and post-schooling system (especially also TVET and community educator competences), restructuring employer-provider (demand-supply) relations, and expansion and diversification of learning pathways (currently the skills for green jobs arena is over-dominated by high-skills learning pathways). • The skills plan will need to offer national level strategic support and local level alignment with emerging priorities and opportunities. Mediating national to local is critical as the roadmap unfolds. Focus should be on capacitating governments and national entities but also consider bottom-up skills processes that could be driven and/or informed by local affected communities.
Occupation and skills	• Development of an occupation and skills atlas. • Undertake an employee workplace-based survey to develop clearer ideas on workplace-based learning needs. • Undertake skills ecosystem mapping in high impact areas (either decrease or increase in jobs). • 'Soft' skills need to be identified and accommodated across various job levels. • Consideration needs to be given to transversal occupations and skills that can be used across various national initiatives such as sector and infrastructure development plans.
Implications for the education sector	• To investigate energy transition-related student throughput (graduations) vs employer demand. • Curriculum review of energy transition-related course content for relevance / specialisms (especially within critical hotspot geographical areas). • Understanding learning pathways in the energy sector through a focused and detailed study of how job seekers can progress within the energy sector. This should include the streams of work associated with core jobs that are going to be impacted by or required to transition South Africa's energy sector. • To review or undertake research to better understand how to enhance partnerships to provide education and training.
Skills planning	• The skills implementation plan should be driven by one accountable entity, yet include government, industry, academia and civil society (at all levels) to avoid duplication, that enabling jobs are adequately provisions, and is responsive to ever-changing uncertainties. • Cross-SETA collaboration to support skills provisioning for the energy transition. • Develop and implement an energy just transition skills implementation plan and a skills hub that can coordinate skills planning processes (governance, time, cost, research)

REFERENCES

Ahmadab, T., Zhang,D., Huangae, C. Zhanga, H. Daia, N. and Songa, Y. and Chen, H. (2021). *Artificial intelligence in sustainable energy industry: Status Quo, challenges and opportunities*. Journal of Cleaner Production, Volume 289, 20 March 2021, 125834. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0959652621000548

AIS. (2019). *ESI generation: Skills forecast 2019*. Australian Industry Standards (AIS). Available at: https://www.australianindustrystandards.org.au/wp-content/uploads/2020/08/UEP-SF-FULL-2019.pdf

AISC. (2022). *National overview: Digital skills*. Australian Industry and Skills Committee (AISC). Available at: https://nationalindustryinsights.aisc.net.au/national/digital-skills

Aldereta, M. (2017). The age of prosumerism: Some micro-economic analysis. *Journal of Theoretical and Applied Electronic Commerce Research,* 12*(3)*. http://dx.doi.org/10.4067/S0718-18762017000300002

Altgen. (2021, May 10). *Exploring the gap between skills and the renewable energy industry*. Available at: https://www.altgen.com/2021/05/10/exploring-the-gap-between-skills-and-the-renewable-energy-industry/

Amaglobeli, D., Hanedar, E., Hong, G. and Thévenot, C. (2022, June 7). Response to high food, energy prices should focus on the most vulnerable. International Monetary Fund (IMF). Available at: https://www.imf.org/en/Blogs/Articles/2022/06/07/blog-response-to-high-food-prices

Appunn, K. (2018, April 25). Sector coupling: Shaping an integrated renewable energy system. *Journalism for the Energy Transition*. Available at: https://www.cleanenergywire.org/factsheets/sector-coupling-shaping-integrated-renewable-power-system

Baral, U. (2021). *The New Wave of the Decentralized Energy Market*. Power October 2021. Available at: https://www.powermag.com/the-new-wave-of-the-decentralized-energy-market/

Block, D., Laxton, D., Zvikomborrero, B., Kamohi, L., Ramashia, F., Kanwa, L., Mashatola, N., Bob, T., Moyo, T., Semenya, A. and Van der Westhuizen, B. (2022, July 4). The impact of poor policy implementation by the government of the republic of South Africa of service delivery. *Regenesys*. Available at: https://www.regenesys.net/reginsights/the-impact-of-poor-policy-implementation-by-the-government-of-the-republic-of-south-africa-on-service-delivery/

Burger, S. (2022, June 8). Just transition holds opportunities, but also risks for South Africa's liquid fuel value chain. *Engineering News*. Available at: https://www.engineeringnews.co.za/article/just-transition-holds-opportunities-but-also-risks-for-south-africas-liquid-fuel-value-chain-2022-06-08

BusinessTech. (2022, January 16). The job sectors with the highest average salaries in South Africa. *BusinessTech*. Available at: https://businesstech.co.za/news/finance/550874/the-job-sectors-with-the-highest-average-salaries-in-south-africa/

BusinessTech. (2022a, November 5). South Africa is betting big on solar and wind - but there's a big problem. *BusinessTech*. Available at: https://businesstech.co.za/news/energy/639641/south-africa-is-betting-big-on-solar-and-wind-but-theres-a-big-problem/

Byström, J. (2019). The impact of electricity prices on the number of workers: A study in the Swedish manufacturing industry. Master's thesis, Umeå Universit, Sweden. Available at: https://docs.google.com/document/d/11QuvzLxyorm5SxJ4nH_P2GWBBP_xYoJG/edit#

Canard, J. (2020, July 27). Renewable energy must become a public good. *Daily Maverick*. Available at: https://www.dailymaverick.co.za/article/2020-07-27-renewable-energy-must-become-a-public-good/

Careers in Energy. (2023). *Working in digitisation and automation in energy*. Available at: https://careersinenergy.ca/plan-your-future/working-in-digitization-and-automation-in-energy/

Central Eastern European Sustainable Energy Network. (2022). *What is sector coupling and what are its benefits?* Available at: https://ceesen.org/en/2022/06/30/what-is-sector-coupling-and-what-are-its-benefits/#:~:text=End%2Duse%20sector%20coupling%20involves,power)%20to%20run%20electric%20vehicles.

Chui, M., Lund, S. and Gumbel, P. (2018, March 2013). How will automation affect jobs, skills, and wages? McKinsey & Company. Available at: https://www.mckinsey.com/featured-insights/future-of-work/how-will-automation-affect-jobs-skills-and-wages

Climate and Development Knowledge Network. (2022). *Fact Sheet Southern Africa - The IPCC'S Sixth Assessment Report Impacts, Adaptation Options and Investment Areas for a Climate-Resilient Southern Africa*. Available at: https://cdkn.org/sites/default/files/2022-03/IPCC%20Regional%20Factsheet_Southern%20Africa_Web.pdf

Climate Investment Funds. (2020). Supporting Just Transitions in South Africa. Available at: https://www.cif.org/sites/cif_enc/files/knowledge-documents/supporting_just_transitions_in_south_africa.pdf

Cloete, R. (2022, January 13). Combating South Africa's alarming dropout rate. *Skills Portal*. Available at: https://www.skillsportal.co.za/content/combating-south-africa%E2%80%99s-alarming-dropout-rate

Cozzi, L. and Motherway, B. (2021, July 6). *The importance of focusing on jobs and fairness in clean energy transitions*. International Energy Agency (IEA). Available at: https://www.iea.org/commentaries/the-importance-of-focusing-on-jobs-and-fairness-in-clean-energy-transitions

Creamer, T. (2022, July 14). IRP 2019 implementation to continue while plan is reviewed, consulted and updated. *Engineering News*. Available at: https://www.engineeringnews.co.za/article/irp-2019-implementation-to-continue-while-plan-is-reviewed-consulted-and-updated-2022-07-14

DHET. (2022). *Finalisation of the critical skills list: Technical report*. Department of Higher Education and Training. Pretoria, South Africa.

DHET. (2022). Skills strategy: Support for the South African economic reconstruction and recovery plan. Department of Higher Education and Training. Pretoria, South Africa.

DMRE. (2019). *Integrated Resource Plan 2019*. Department of Mineral Resources and Energy (DMRE). Available at: http://www.energy.gov.za/IRP/2019/IRP-2019.pdf

DMRE. (2022a). *The South African Energy Sector Report 2021*. Department of Mineral Resources and Energy (DMRE). Available at: www.energy.gov.za/files/media/explained/2021-South-African-Energy-Sector-Report.pdf

DMRE. (2022b). *Department of Mineral Resources and Energy Annual Performance Plan for 2022 – 2023*. Available at: https://static.pmg.org.za/2022-23_APP_-_Master_Doc_29_March_2022_with_signatures.pdf

DMRE. (2022c). *Nuclear energy*. Department of Mineral Resources & Energy (DMRE). Available at: https://www.energy.gov.za/files/esources/nuclear/nuclear_back.html#:~:text=Its%20first%20commercial%20nuclear%20power,employs%20about%202%20700%20people.

Ebrahim, N. (2022, December 25). The most in-demand jobs and skills in South Africa: Report. *News24*. Available at: https://www.news24.com/fin24/economy/the-most-in-demand-jobs-and-skills-in-south-africa-report-20221225

Economist Intelligence Unit [EIU] (2023). *Energy outlook 2023 Surviving the energy crisis*. Available at: https://www.eiu.com/n/campaigns/energy-in-2023/?utm_source=google&utm_medium=ppc&utm_campaign=industries-in-2023&gclid=Cj0KCQiA8aOeBhCWARIsANRFrQHRwF0uKvNzMKfdKK9XbBsaVzURa4_ZKZoBwRlPiHMJSq-QVVTKahAaAs6bEALw_wcB#mktoForm_anchor

EESI. (2021). *Fact sheet: Climate jobs 2021*. Environmental and Energy Study Institute (EESI). Available at: https://www.eesi.org/papers/view/fact-sheet-climate-jobs

ernational Energy Agency (IEA). Available at: https://www.iea.org/topics/energy-security

Eskom. (2022). *Medium Term System Adequacy Outlook*. Available at: https://www.eskom.co.za/wp-content/uploads/2022/10/Medium-Term-System-Adequacy-Outlook-2023-2027.pdf

Eskom. (2023). *Vacancies.* Available at: https://secapps.eskom.co.za/sites/recruitment/Pages/Vacancies.aspx?&&p_SortBehavior=0&p_Created=20230116%2009%3a04%3a42&p_ApplicantDepartment=HV%20Plant&&PageFirstRow=1&&View={92F05D3C-4D6B-4DF5-A3E2-9B1648EDAB83}

Evans, J. (2021, November 8). The real deal with renewable energy in South Africa: Unpacking the suite of options. *Daily Maverick*. Available at: https://www.dailymaverick.co.za/article/2021-11-08-the-real-deal-with-renewable-energy-in-south-africa-unpacking-the-suite-of-options/

EWSETA. (2021). *Sector skill plan 2022/23*. Energy and Water Sector Education & Training Authority (EWSETA). Available at: https://ewseta.org.za/sector-skills-plan-2022-23/

Gatticchi, G. (November 5, 2020). As many as 120,000 jobs at risk in SA in shift to renewable energy. *Business Day*. Available at: www.businesslive.co.za/bd/national/2020-11-05-as-many-as-120000-jobs-at-risk-in-sa-in-shift-to-renewable-energy/

Gerber, J. (2022, November 20). Work under way to stop power cuts, says Presidency after Stage 5 load shedding announced. *News24*. Available at: https://www.news24.com/news24/southafrica/news/work-under-way-to-stop-power-cuts-says-presidency-after-stage-5-load-shedding-announced-20221120

GETI. (2021). The Global Energy Talent Index report 2021: Opportunity from uncertainty. Global Energy Talent Index (GETI). Available at: https://f.hubspotusercontent30.net/hubfs/3277184/Gated%20PDFS/GETI_Report_2021.pdf?utm_campaign=GETI%202021&utm_medium=email&_hsmi=105783925&_hsenc=p2ANqtz-_jKh4WbmxMNZqfsNBor5U8qpPk28RJTG3FGQ4ZPegTBKiUieg4d-FIMndfMpqqfPh1XpH8iuo5UXHODbl3bx0Zm5Wpyg&utm_content=105783925&utm_source=hs_automation

Githahu, M. (2023, January 13). Nersa's approval of 18.6% electricity price hike for Eskom a 'very bitter pill to swallow.' *IOL*. Available at: https://www.iol.co.za/capeargus/news/nersas-approval-of-186-electricity-price-hike-for-eskom-a-very-bitter-pill-to-swallow-cac660e3-8efc-4850-9085-33de6a78c30f

Hako, N. (2022, March 10). Research outlines key findings on the role of gas in South Africa's energy transition. ESI Africa. Available at: https://www.esi-africa.com/southern-africa/research-outlines-key-findings-on-the-role-of-gas-in-south-africas-energy-transition/

Hanto, J., Krawielicki, L., Krumm, A., Moskalenko, N., Löffler, K., Hauenstein, C., and Oei, P. (2021). Effects of decarbonization on the energy system and related employment effects in South Africa. *Environmental Science & Policy*, 124, 73-84. Available at: https://doi.org/10.1016/j.envsci.2021.06.001

Hermanus, L. (2022). Employment metrics in South Africa's electricity value chains: Creating a basis for coherent discourse and decision-making. [Policy Brief 4/2022]. Trade & Industrial Policy Strategies (TIPS). Available at https://www.tips.org.za/policy-briefs/item/download/2251_9b4d44b9398c6c56e6b5aeaf86f2c293

IEA, (2017). *Digitalisation and energy*. International Energy Agency (IEA). Available at: https://www.iea.org/reports/digitalisation-and-energy

IEA. (2022). *Energy security: Reliable, affordable access to all fuels and energy sources.* Int

IEA. (2022). *World energy employment*. International Energy Association (IEA). Available at: https://iea.blob.core.windows.net/assets/a0432c97-14af-4fc7-b3bf-c409fb7e4ab8/WorldEnergyEmployment.pdf

IEA. (2022c). *Climate Resilience*. International Energy Agency (IEA). Available at: https://www.iea.org/reports/climate-resilience

ILO. (2013). *Providing clean energy and energy access through cooperatives*. International Labour Organisation (ILO). Available at: https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_233199.pdf

ILO. (2023). *Why does climate change matter for employment?* International Labour Organisation (ILO). Available at: https://www.ilo.org/global/topics/green-jobs/areas-of-work/climate-change/lang--en/index.htm

Indeed. (2022). *Eskom Holdings Limited salaries in South Africa.* Available at: https://za.indeed.com/cmp/Eskom-Holdings-Limited/salaries

IRENA and ILO. (2021). Renewable Energy and Jobs: Annual Review 2021. International Renewable Energy Agency (IRENA) and the International Labour Organisation (ILO). Available at: https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_823807.pdf

IRENA. (2019). Renewable energy: A gender perspective. International Renewable Energy Agency (IRENA). Available at: https://www.irena.org/publications/2019/Jan/Renewable-Energy-A-Gender-Perspective

IRENA. (2022). *Renewable energy and jobs: Annual review 2022.* International Renewable Energy Agency (IRENA). Available at: https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/documents/publication/wcms_856649.pdf

IRENA. (2022a). *Sector coupling: A key concept for accelerating the energy transformation.* International Renewable Energy Agency (IRENA) Coalition for Action. Available at: https://mc-cd8320d4-36a1-40ac-83cc-3389-cdn-endpoint.azureedge.net/-/media/Files/IRENA/Coalition-for-Action/Publication/IRENA_Coalition_sector_coupling_2022.pdf?rev=e228888a1cea417ebbef42cb69e99c89

Kamer, L. (2022). Renewable energy employment in Africa 2020, by region. Statista. Available at: https://www.statista.com/statistics/1297534/renewable-energy-employment-in-africa-by-region/

Khumalo, S. (2021, September 14). Mining sector shed 23 000 jobs between 2012 and 2019 as gold lost its glitter. *News24*. Available at: https://www.news24.com/fin24/companies/mining-sector-shed-23-000-jobs-between-2012-and-2019-as-gold-lost-its-glitter-20210914

MacColl, B. (2022). Personal communication. Electric Power Research Institute, Palo Alto California.

Makeitfuture. (2022). What is the difference between digitalization and automation? Available at: https://www.makeitfuture.com/automation/difference-between-digitalization

Marin, G. and Vona, F. (2017). *The impact of energy prices on employment and environmental performance: Evidence from French manufacturing establishments.* Sustainability Seeds. Available at: https://www.sustainability-seeds.org/papers/RePec/srt/wpaper/0717.pdf

Marwala, T. and Mpdei, L. (2022, November 29). If we want to fix our economy, we must increase university graduation rates. *Daily Maverick*. Available at: https://docs.google.com/document/d/11QuvzLxyorm5SxJ4nH_P2GWBBP_xYoJG/edit#

Meridian Economics. (2018). *An overview of the employment implications of the South African power sector transition*. [Briefing paper]. South African Wind Energy Association (SAWEA). Available at: https://sawea.org.za/wp-content/uploads/2018/07/Employment-implications-SA-power-sector-transition_final.pdf

MOGA. (2018). *Marine, oil and gas career landscape*. Marine, Oil & Gas Academy (MOGA). Available at: https://moga.saoga.org.za/careers

Montmasson-Clair, G. (2020). *A case for renewable energy in South Africa's post-lockdown economic recovery stimulus package*. [Policy brief 13/2020]. Trade & Industrial Policy Strategies (TIPS). Available at: www.tips.org.za/images/TIPS_Policy_Brief_A_case_for_renewable_energy_in_South_Africas_post_lockdown_economic_recovery_stimulus_package_May_2020.pdf

Montmasson-Clair, G. (2021). *Making sense of jobs in South Africa's just energy transition: Managing the impact of a coal transition on employment.* Trade & Industrial Policy Strategies (TIPS). Available at: www.tips.org.za/images/Policy_Brief_Making_sense_of_jobs_in_South_Africas_just_energy_transition_Managing_the_impact_of_a_coal_transition_on_employment_April_2021.pdf

Mousavi, F., Nazari-Heris, M., Mohammadi-Ivatloo, B. and Asadi, S. (2021). Energy market fundamentals and overview. Chapter 1 in: Energy Storage in Energy Markets, Uncertainties, Modelling, Analysis and Optimization 2021, Pages 1-21. Available at: https://www.sciencedirect.com/science/article/pii/B9780128200957000054

O'Regan, V. (2022, January 21). South Africa's matric pass rate improves slightly to 76.4% despite 'extremely difficult circumstances.' *Daily Maverick.* Available at:

https://www.dailymaverick.co.za/article/2022-01-21-south-africas-matric-pass-rate-improves-slightly-despite-extremely-difficult-circumstances/

Okunlola, A., Jacobs, D., Ntuli, N., Fourie, R., Borbonus, S., Nagel, L. and Helgenberger, S. (Eds). (2019). Future skills and job creation through renewable energy in South Africa: Assessing the co-benefits of decarbonising the power sector. COBENEFITS. Available at: https://www.cobenefits.info/wp-content/uploads/2019/03/COBENEFITS-Study-South-Africa-Employment.pdf

Patel, M., Makgetla, N., Maseko, N. and Montmasson-Clair, G. (2020). Sector jobs resilience plan: Coal value chain. Trade & Industrial Policy Strategies (TIPS). Available at: https://www.westerncape.gov.za/110green/files/atoms/files/Final%20Sector%20Jobs%20Resilience%20Plans%20for%20Coal%20Value%20Chain%202020_0.pdf

Peyton, N. (2022, November 16). Eskom says maintenance work could worsen load shedding for a year. *BizCommunity*. Available at: https://www.bizcommunity.com/Article/196/693/233560.html

Presidential Climate Commission. (2022). *A Framework for a Just Transition in South Africa*. Available at: https://pccommissionflow.imgix.net/uploads/images/A-Just-Transition-Framework-for-South-Africa-2022.pdf

Renkamp, B. and Bhuyan, R. (2017). Chapter 14: The social shaping of nuclear energy technology in South Africa, in D. Arent (Editor), The Political Economy of Clean Energy Transitions. Oxford University Press, Oxford, United Kingdom. Available at: https://academic.oup.com/book/16547/chapter/172511860

Republic of South Africa. (2019, February 14). *Renewable energy programme attracts R209.4 billion to SA economy*. Available at: https://www.sanews.gov.za/south-africa/renewable-energy-programme-attracts-r2094-billion-sa-economy

Republic of South Africa. (2021a). *First nationally determined contribution under the Paris Agreement*. Available at: https://unfccc.int/sites/default/files/NDC/2022-06/South%20Africa%20updated%20first%20NDC%20September%202021.pdf

Republic of South Africa. (2021b). *Hydrogen Society Roadmap for South Africa*. Available at: https://www.google.com/search?q=hydrogen+society+roadmap+south+africa&rlz=1C1RFPM_enZA902ZA902&oq=hydrogen+society+roadmap&aqs=chrome.1.69i57j35i39j0i512j0i22i30l4j0i390.7808j0j15&sourceid=chrome&ie=UTF-8

Republic of South Africa. (2021c). *Climate Change Bill*. Available at: https://www.gov.za/sites/default/files/gcis_document/202203/b9-2022.pdf

SA Government. (2022). *The national government handbook: South Africa 2022*. Available at: https://www.yesmedia.co.za/the-national-government-handbook/

SADC. (2020). *Regional indicative strategic development plan (RISDP) 2020–2030*. Southern African Development Community (SADC). Available at: https://www.sadc.int/document/sadc-regional-indicative-strategic-development-plan-risdp-2020-2030

Sapia. (2019). *The economic contribution of the downstream oil industry to South Africa in 2019: Executive summary presentation*. South African Petroleum Industry Association (SAPIA). Available at: https://www.sapia.org.za/wp-content/uploads/2022/04/SAPIA_Economic-Impact-Assessment.pdf

Sarkodie, S. and Adams, S. (2020). *Electricity access and income inequality in South Africa: Evidence from Bayesian and NARDL analyses*. Energy Strategy Reviews 29. Available at:

https://nordopen.nord.no/nord-xmlui/bitstream/handle/11250/2669830/Sarkodie.pdf?sequence=4&isAllowed=y

Sihlobo, W. (2021, September 20). Poor implementation is a major issue for policy credibility in South Africa's agriculture. *Agricultural Economics Today.* Available at: https://wandilesihlobo.com/2021/09/20/poor-implementation-is-a-major-issue-for-policy-credibility-in-south-africas-agriculture/

Skidmore, Z. (2021, November 3). COP26: South Africa to receive $8.5bn to end coal use. *Mining Technology*. Available at: https://www.mining-technology.com/news/south-africa-partnership-coal-reliance/

Smart Energy International. (May 15, 2019). Skills shortages in South Africa. *Smart Energy International*. www.smart-energy.com/industry-sectors/energy-grid-management/skills-shortages-in-south-africa-2/

Statista. (2022). *Number of people employed by South Africa's coal mining industry from 2011 to 2021.* Available at: https://www.statista.com/statistics/1311307/south-africa-coal-mining-employment/

StatsSA. (2018). *Overcoming Poverty and Inequality in South Africa an Assessment of Drivers, Constraints and Opportunities*. Available at: https://www.statssa.gov.za/wp-content/themes/umkhanyakude/documents/South_Africa_Poverty_and_Inequality_Assessment_Report_2018.pdf

StatsSA. (2022). *Quarterly employment statistics (QES): June 2022*. Statistics South Africa (StatsSA). Available at: https://www.statssa.gov.za/publications/P0277/P0277June2022.pdf

StatsSA. (2022a). *Electricity, gas and water supply industry, 2021*. Statistics South Africa (StatsSA). Available at: https://www.statssa.gov.za/publications/Report-41-01-02/Report-41-01-022021.pdf

Stolar, S. (2021, June 14). *USAID empowering women in Africa's energy sector*. The Borgen Project. Available at: https://borgenproject.org/women-in-africans-energy-sector/#:~:text=Gender%20and%20the%20Energy%20Sector%20Studies%20by%20the,to%2020%25%20of%20the%20general%20power%20sector%20workforce.

TIPS. (2022). *Employment metrics in South Africa's electricity value chains: Creating a basis for coherent discourse and decision-making*. Available at: file:///C:/Users/wpoul/Downloads/TIPS_WWF_SA_Just_Urban_Transitions_Policy_Brief_Employment_Metrics_in_South_Africas_Electricity_Value_Chains%20(1).pdf

Torkington, S. (2023, January 10). These are the 4 skills you'll need in the workplace of the future. *World Economic Forum*. Available at: https://www.weforum.org/agenda/2023/01/skills-jobs-future-workplace/

Trace, S. (2020, October 29). *Increasing women's participation in the energy sector: Addressing the challenges*. Energy and Economic Growth. Available at: https://www.energyeconomicgrowth.org/blog/increasing-womens-participation-energy-sector-addressing-challenges

UNFCCC. (2023). *Adaptation and Resilience*. United Nations Framework Convention on Climate Change. Available at: https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/introduction#:~:text=Adaptation%20refers%20to%20adjustments%20in,opportunities%20associated%20with%20climate%20change.

United Nations. (2023). *For a livable climate: Net-zero commitments must be backed by credible action.* Available at: https://www.un.org/en/climatechange/net-zero-coalition

Vasseur, L. and Jones, M. (2015). Adaptation and resilience in the face of climate change: protecting the conditions of emergence through good governance. Available at: https://sustainabledevelopment.un.org/content/documents/6579124-Vasseur-Adaptation%20and%20resilience%20in%20the%20face%20of%20climate%20change.pdf

Wallach, O. (2022, March 25). *How many jobs could the clean energy transition create?* World Economic Forum. Available at: https://www.weforum.org/agenda/2022/03/the-clean-energy-employment-shift-by-2030/

Wits REAL. (2021). *Linking education and work in the South African energy and water supply sectors*. Centre for Researching Education and Labour (REAL), University of the Witwatersrand and the Energy and Water Sector Education and Training Authority (EWSETA), Johannesburg, South Africa.

Wits REAL. (2021). *Linking education and work in the South African energy and water supply sectors.* Energy and Water Energy Education and Training Authority (EWSETA). Johannesburg, South Africa.

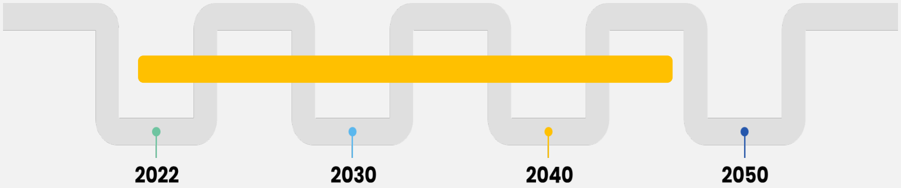
Wits REAL. (2022). An assessment of skills supply and demand for renewable energy, energy efficiency and regional energy integration in the SADC region. International Labour Organisation (ILO). Unpublished.

Woosey, J. (2021, March 4). Here's how South African fuel prices have changed in the last 10 years. *IOL.* Available at: https://www.iol.co.za/motoring/industry-news/heres-how-south-african-fuel-prices-have-changed-in-the-last-10-years-5acb2415-3cf9-47df-8923-3a06c8b07bd9

World Economic Forum (WEF). (2022). *Global Risk Report, 2022*. Available at: https://www.weforum.org/reports/global-risks-report-2022/

APPENDICES

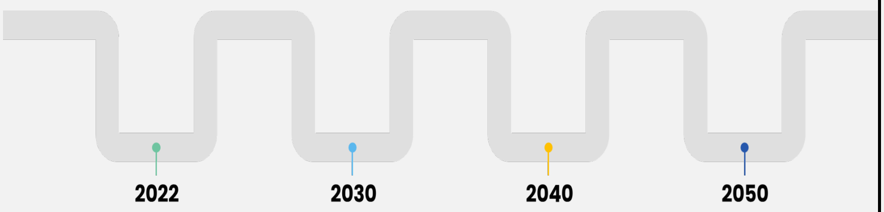
Appendix 1: Detailed list of the occupations required per trend over time

Trend: The widening energy cost gap	
Time horizon	

Impact on the world of work	• Increased energy prices impact vulnerable households - policy makers need to ensure protection measures e.g., laws and subsidies to mitigate social impact of rising prices.
	   ○ High prices can result in theft or an inability to pay (SADC, 2020). Energy safety nets can be considered to support low-economic communities with schemes like free basic electricity. In addition, the implementation of theft protection mechanisms need to be put in place. Individuals will be required to advise and implement such mechanisms.
	• An increase in the price of electricity can have a short-term negative impact on workers in all economic sectors, notably those that are energy intensive e.g. industrial (chemical and petrochemical, and iron and steel) and mining sectors (DMRE, 2022a). However, increased prices can lead to an optimisation in energy use resulting in cost savings and therefore job retention. Vulnerability to energy price shocks will require:
	   ○ Employers to improve management or control of energy consumption, and implement energy efficiency policy and reduction activities, and
	   ○ Householders to better understand and reduce their energy usage.
	• Government officials (advisors) and regulators are required to develop and implement energy sector master plan(s) to recognise universal access to reasonably priced electricity, develop and advise on electricity tariffs, enable the trading of privately produced energy to generate income, and to incentivise energy efficiency practices, especially in energy intensive industries.

Minor occupation groups	• Legislators and Senior Officials • Managing Directors and Chief Executives • Professional Services Managers • Mathematicians, Actuaries and Statisticians • Finance Professionals • Social and Religious Professionals • Sales, Marketing and Public Relations Professionals • Legal Professionals • Regulatory Government Associate Professionals • Legal, Social and Religious Associate Professionals
Types of priority occupations required for the transition. Also see the Climate change: Achieving net zero carbon emissions by 2050 trend, in particular energy efficiency (to reduce energy costs).	

2023 - 2030 (Short term)	2031 - 2040 (Medium term)	2041 - 2050 (Long term)
● Community Liaison Officer ● Communication Coordinator ● Energy Broker ● Energy Economist ● Lawyer ● Legal Advisor ● Legal Analyst ● Policy Advisor ● Policy and Planning Manager ● Policy Consultant / Officer / Planner ● Policy Development Manager ● Pricing Clerk / Analyst / Estimator ● Public Policy Manager ● Regulatory Affairs Officer ● Trade Policy Advisor	Carry over of occupations listed in the short term, plus an increased focus on the following: ● Finance Director ● Finance Manager ● Financial Market Dealer ● General Accountant ● Programme or Project Manager ● Security Advisor ● Security Guard ● Security Safety and Emergency Services Manager	Carry over of occupations listed in the short and medium term, plus an increased focus on the following: ● Auditor

Trend: Deteriorating energy security	
Time horizon	
Impact on the world of work	● To transform the generation of electricity into an effective and efficient operation that the country's businesses and population can rely on, good leadership and management, union negotiation; policy development; planning, implementation (including quality control) and monitoring; risk mitigation (including security); financing; coordination and core maintenance skills are required (Peyton, 2022). ○ Given the need for maintenance skills (an estimated shortfall of 40,000 artisans in the country), emphasis on electrical / maintenance technician and planning training is critical (accredited / certified) (Alphonsus et al., 2021). ○ Recruitment of skilled personnel, including former Eskom personnel, to work with current permanent teams to resolve urgent issues and to transfer skills to permanent staff (Gerber, 2022). ● With the transmission grid facing constraints there is a need to expand the grid, to incorporate renewables and mini grids (see Climate change - achieving net zero by 2050 trend below). This will require individuals with the knowledge and skills to seek investment; finance, coordinate and implement the expansion. It is likely that these skills will be required in more decentralised

<table>
<tr><td></td><td colspan="2">nodes of activity e.g. districts and municipalities (see the evolving energy markets trend below).</td></tr>
<tr><td>Minor occupation groups</td><td colspan="2">Legislators and Senior Officials
Managing Directors and Chief Executives
Mathematicians, Actuaries and Statisticians
Engineering Professionals
Architects, Planners, Surveyors and Designers
University and Higher Education Teachers
Vocational Education Teachers
Finance Professionals
Legal Professionals
Physical and Engineering Science Technicians
Process Control Technicians
Financial and Mathematical Associate Professionals
Sales and Purchasing Agents and Brokers
Machinery Mechanics and Repairers
Electrical Equipment Installers and Repairers</td></tr>
<tr><td colspan="3">Types of priority occupations required for the transition</td></tr>
<tr><td>2023 - 2030
(Short term)

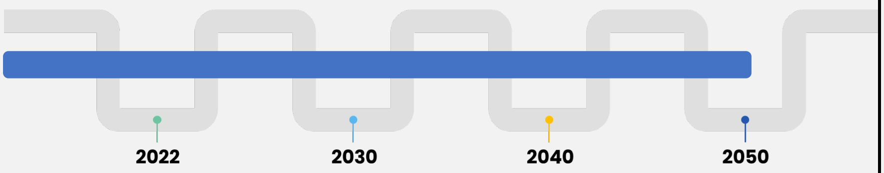
Maintenance and infrastructure:
Boilermaker / welder
Construction Manager
Control & Instrumentation Engineer
Electric Power Generation Engineer
Electric Substation Operations Manager
Electrical Engineer
Electrical Engineering Technician
Electrical Engineering Technologist
Electrical Design Engineer
Electrical Inspector Construction
Electrical Inspector Lines
Electrician
Electronic Engineering Technician
Engineering Manager
Fossil Power Plant Process Operator
Instrument Mechanician (Industrial</td><td>2031 - 2040
(Medium term)

Carry over of occupations listed in the short term, plus an increased focus on the following:
Boilermaker Educator
Electrical Technician Educator</td><td>2041 - 2050
(Long term)

Carry over of occupations listed in the short and medium term</td></tr>
</table>

Instrumentation & Process Control) • Linesman • Maintenance Planner • Maintenance Technologist • Mechanical Engineer • Mechanical Engineering Technologist • Metre Technician • Operations Manager (Production) • Pipe Fitter • Power Distribution Engineer • Power Generation Operations Manager • Power Systems Engineer • Power Transmission Engineer • Process Operator System management / operations: • Cost Engineer • Cost Modelling / Industry Analyst • Debtors Manager • Energy Specialist • Environmental and Occupational Health Inspectors and Associates • Finance Director • General Accountant • General Manager Public Service • Health and Safety Officer / Coordinator / Professional • Human Resource Manager • Independent Power Producer (IPP) Specialist • Internal auditor • Investment Advisor • Investment Analyst • Investment Research Analyst • Municipal Manager • Planning & Development Manager • Policy Advisor • Policy Consultant / Officer / Planner		

• Power Distribution Manager • Power Distribution Planner • Procurement Administrator / Coordinator / Officer • Procurement Manager • Programme Evaluator • Programme or Project Manager • Property Portfolio and Asset Manager • Prosecutor • Quality Assurance / Systems Auditor • Research and Evaluation Analyst • Security Advisor • Security Guard • Senior Government Official • Shutdown Coordinator / Planner • Statistical Modeller • Supply Chain Practitioner		

Trend: Climate change: Achieving net zero carbon emissions by 2050	
Time horizon	
Impact on the world of work	• A transition to low- and net zero carbon will require a change in the country's energy mix, new technologies, new energy pathways and revised cohesive plans, aligned policy, new operating and integration models and new employment pathways. This will present new work opportunities, likely an increase in jobs (estimated 180,000 jobs by 2035 and 468,000 jobs by 2050 via decarbonisation of the energy sector), but also timing and employment risks. Long-term transition planning, guidance and financing is critical (Burger, 2022; Cozzi and Motherway, 2021; Hanto et al., 2021; Okunlola et al., 2019), and requires up to date, aligned and clear vision and policy e.g. Integrated Resource Plan (IRP) (Creamer, 2022; Evans, 2021). • This significant shift will require a detailed review of current education and skills provisioning in the country and how it aligns with short, medium and long term skills demands. This is likely to result in the refinement and development of new education programmes, courses, research and curricula (Heppelthwaite et al., 2022). Shift from fossil fuels / decarbonisation:

	- A shift away from and reduction in use of fossil-fuels will result in reduced employment and affect local communities associated with coal mining and logistics, and most likely the oil and gas sectors too (Patel et al., 2020; Skidomore, 2021)[4]. - The shift away from coal is estimated to result in significant job losses in the sector - 48% by 2050 (Montmasson-Clair 2021; Okunlola et al., 2019). This shift will affect management and professional, process operators, maintenance personnel and artisan, truckers and clerical personnel working in these sectors. While most of these occupations listed are likely to find alternative employment outside these sectors, coal miners and process operators will be the most affected and/or unlikely to find like-for-like positions. Approximately 80,000 coal miners and 120,000 value chain jobs are at risk. This is compounded by 80% of the coal workforce having a matric or less. Therefore education, upskilling and reskilling will be critical to ensure e.g. coal miners can easily move into other sectors (Burger, 2022; Gatticchi, 2020; Hanto et al., 2021; Montmasson-Clair, 2020; Patel et al., 2020). - This shift will also have an impact on the localisation of jobs e.g. from Mpumalanga to Northern Cape (solar PV). There is a need to ensure no one is left behind e.g. alternative job provisioning in current location, or relocation is considered, well planned and targeted in communities that are impacted (Cozzi and Motherway, 2021; Hanto et al., 2021; IRENA and ILO, 2021). - Skills will be required in labour force and community stakeholder engagement and negotiation to realise a just transition for this sector of the workforce and associated communities (Patel et al., 2020). - Decommissioning or retrofitting of coal-fired plants will require unique skills and knowledge, as well as upskilling of the current coal-fired power workforce (EWSETA, 2021; Meridian Economics, 2018). Renewable energy (solar, wind, biomass): - The growth of the renewable energy sector will require the necessary jobs and skills to fulfil the sector's growth potential, including jobs in planning and strategy, research and development (R&D), technology manufacture, installation and construction, operations, management and maintenance, sales and marketing, and associated clerical and technical work. Increasing the share of renewables will increase employment opportunities (Cozzi and Motherway, 2021; Okunlola et al., 2019), with this demand partially substituting the decline in coal-related jobs (Hanto et al., 2021). While predictions for renewable energy job creation numbers vary, the following have been suggested: Wind (130,000 direct and in-direct up to 2030) (Burger, 2022). - Currently there is a scarcity of specialist renewable energy technical and managerial skills. This will require the education,

[4] Due to the numerous strands of occupation and skills considerations and contexts, this report cannot do the impact on fossil-fuel jobs justice. However, the authors wish to acknowledge the significant work undertaken in this area in the COBENEFITS project (see e.g. Okunlola et al., 2019), the Presidential Climate Commission (see e.g. PCC, 2022) and TIPS (see e.g. Montmasson-Clair, 2020 and 2021).

<table>
<tr>
<td></td>
<td colspan="2">training and upskilling of e.g. engineers and technicians to shift into renewables (BusinessTech, 2022a; Altgen, 2021).

There is likely to be a shift away from corporate monopolies to privatisation and decentralisation. More responsibility will fall on local municipalities to procure, negotiate and set tariffs, trade and manage the electricity generated within their jurisdictions (see the Evolving Energy Markets trend below).

Clean energy (automotive, industry, green hydrogen, nuclear)

Clean energy, such as efficiency, new technologies and automotive will require new roles or upskilling of the existing workforce in industry to manufacture, procure, install, maintain and monitor low-emission products e.g. electric vehicles, appliances and technologies e.g. green hydrogen (Cozzi and Motherway, 2021).

Energy efficiency:

See the widening energy cost gap trend above.
</td>
</tr>
<tr>
<td>Minor occupation groups</td>
<td colspan="2">
Legislators and Senior Officials
Managing Directors and Chief Executives
Business Services and Administration Managers
Sales, Marketing and Development Managers
Manufacturing, Mining, Construction and Distribution Managers
Life Science Professionals
Engineering Professionals
Architects, Planners, Surveyors and Designers
University and Higher Education Teachers
Vocational Education Teachers
Finance Professionals
Sales, Marketing and Public Relations Professionals
Legal Professionals
Social and Religious Professionals
Physical and Engineering Science Technicians
Mining, Manufacturing and Construction Supervisors
Process Control Technicians
Sales and Purchasing Agents and Brokers
Regulatory Government Associate Professionals
Sheet and Structural Metal Workers, Moulders and Welders
Machinery Mechanics and Repairers
Electrical Equipment Installers and Repairers
Mining and Construction Labourers
</td>
</tr>
<tr>
<td colspan="3">Types of priority occupations required for the transition</td>
</tr>
<tr>
<td>2023 - 2030
(Short term)

Shift from fossil fuels / decarbonisation:

Benefits Manager
Business / Community / Disability Liaison Officer
Campaign Organiser
</td>
<td>2031 - 2040
(Medium term)

Carry over of occupations listed in the short term, plus an increased focus on the following:

Shift from fossil fuels / decarbonisation:</td>
<td>2041 - 2050
(Long term)

Carry over of occupations listed in the short and medium term.</td>
</tr>
</table>

• Climate Change Analyst • Climate Change Scientist • Communication Coordinator • Corporate Communication Manager • Economic Advisor • Economic Consultant • Education Specialist • Education Training and Skills Development Manager • Employee Relations Advisor • Employment Relations Officer • Energy Economist • Energy Specialist • Environmental Scientist • Environmentalist • Finance and Insurance Consultant • Green Economy Specialist • Human Resource Manager • Journalist • Labour Dispute Enforcement Agent • Lawyer • Legal Advisor • Local Economic Development Manager • Local Economic Development Specialist • Mine Overseer (Projects) • Mineral Resources Manager • Mining Engineer • Mining Manager • Policy and Planning Manager • Policy Consultant / Officer / Planner • Policy Development Manager • Principal Disputes Referee • Programme or Project Manager • Public Policy Manager • Risk / Planning / Review / Analyst	• College Lecturer • Environmental Educator • Mine Closure Engineer • Mine Closure Manager • Programme Evaluator • Research and Evaluation Analyst • TVET Educator • University Lecturer	

• Skills Development Strategist • Social Scientist • Statistical Modeller • Trade Union Official • Urban and Regional Planner		
Renewable energy (solar, wind, biomass, marine): • Business Consultant • Business Development Manager • Chemical Engineer • Chemical Engineering Technician • Circular Economy Specialist • Civil Construction Worker • Civil Engineer • Civil Engineering Technician • Civil Engineering Technologist • College Lecturer • Construction Engineer • Construction Manager • Construction Project Manager • Construction Site Manager • Contract Manager • Contracts Lawyer • Contracts Officer • Control & Instrumentation Engineer • Corporate General Manager • Cost Engineer • Director (Enterprise / Organisation) • Draughtsperson • Electrical Design Engineer • Electrical Engineer • Electrical Engineering Technician • Electrical Engineering Technologist • Electrician • Employee Relations Advisor • Energy Economist	Renewable energy (solar, wind, biomass, marine): Carry over of occupations listed in the short term, plus an increased focus on the following: • Biochemical Engineer • Biochemical Engineer • Biofuels Processing Technicians • Biofuels Production Manager • Biofuels/Biodiesel Technology and Product Development Managers • Compliance Officer • Engineering Educator • Environmental Educator • Maintenance Planner • Maintenance Technologist • Marine Engineer • Marine Engineering Technologist • Marketing Practitioner • Property Portfolio and Asset Manager • Sales and Marketing Manager • Sales Representative • Science Educator • Waste Management Practitioner • Wave Energy Specialist	Renewable energy (solar, wind, biomass, marine): Carry over of occupations listed in the short and medium term, plus an increased focus on the following: • Biomass Power Plant Manager • Bioprocess Engineer

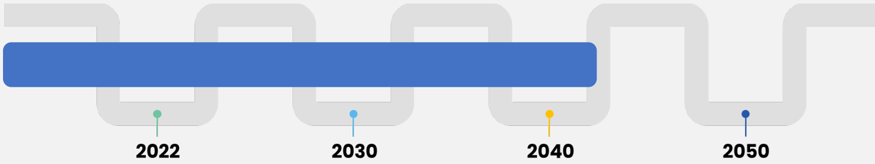
• Energy Specialist • Energy Storage Advisor • Energy Storage Engineer • Energy Storage Technician • Environmental Engineer • Environmental Manager • Environmental Scientist • Finance Director • Finance Manager • Financial Business Analyst • Financial Markets Investment Advisor • Financial Markets Practitioner • Fossil Power Plant Process Controller • Grid Integration Manager • Health and Safety Officer / Coordinator / Professional • Human Resource Manager • Independent Power Producer (IPP) Specialist • Instrument Mechanician (Industrial Instrumentation & Process Control) • Investment Advisor • Investment Analyst • Lawyer • Mechanical Engineer • Mechanical Engineering Technologist • Operations Manager (Production) • Pipe Fitter • Policy Consultant / Officer / Planner • Pollution and Waste Manager • Power Distribution Engineer • Power Generation Operations Manager • Power Systems Engineer • Power Transmission Engineer • Process Design Engineer • Procurement Administrator / Coordinator / Officer		

• Procurement Manager • Programme or Project Manager • Proposal Engineer • Quantity Surveyor • Regulatory Affairs Officer • Renewable Energy Engineer • Renewable Energy Manager • Renewable Energy Specialist • Renewable Energy Technologist • Research and Development Manager • Research Consultant • Risk / Planning / Review / Analyst • Safety, Health, Environment and Quality (SHE&Q) Practitioner • Social Scientist • Solar Business Development Manager • Solar Photovoltaic Engineer • Solar Photovoltaic Installer • Solar Photovoltaic Specialist • Solar Photovoltaic Technologist • Statistical Modeller • TVET Educator • University Lecturer • Wind Energy Operations Manager • Wind Energy Specialist • Wind Turbine Engineer • Wind Turbine Technologist		
Clean energy (automotive/ transportation, industry, green hydrogen, gas/ nuclear): • Business Consultant • Business Development Manager • Circular Economy Specialist • Contract Manager • Contracts Lawyer • Contracts Officer	Clean energy (automotive/ transportation, industry, green hydrogen, gas/ nuclear): Carry over of occupations listed in the short term, plus an increased focus on the following: • Automotive Engineer • Automotive Engineering Technician	Clean energy (automotive/ transportation, industry, green hydrogen, gas/ nuclear): Carry over of occupations listed in the short and medium term, plus an increased focus on the following: • Electric Vehicle Station Attendant

• Corporate Communication Manager • Corporate General Manager • Cost Engineer • Electrical Design Engineer • Electrical Design Technician • Energy Economist • Environmental Engineer • Environmental Manager • Environmental Scientist • Finance Director • Finance Manager • Financial Business Analyst • Financial Markets Investment Advisor • Financial Markets Practitioner • Green Hydrogen Analyst • Green Hydrogen Specialist • Health and Safety Officer / Coordinator / Professional • Human Resource Manager • Investment Advisor • Investment Analyst • Lawyer • Mineral Economist • Nuclear Energy Engineer • Nuclear Energy Technologist • Nuclear Engineering Technician • Nuclear Physicist • Nuclear Power Plant Process Controller • Nuclear Power Plant Process Operator • Operations Manager (Production) • Policy Consultant / Officer / Planner • Process Design Engineer • Process Design Technician • Proposal Engineer • Radiation Control/ Nuclear Monitoring Technician	• Civil Construction Worker • Compliance Officer • Construction Engineer • Construction Project Manager • Construction Site Manager • Electrical Educator • Electrical Engineer • Electrical Engineering Technician • Electrical Engineering Technologist • Electrician • Engineering Educator • Engineering Manager • Fuel Cell Engineer • Fuel Cell Technician • Green Hydrogen Business Development Manager • Logistics Manager • Maintenance Technologist • Marketing Practitioner • Pipe Fitter • Power Systems Engineer • Procurement Administrator / Coordinator / Officer • Procurement Manager • Programme or Project Manager • Quality Assurance / Systems Auditor • Safety, Health, Environment and Quality (SHE&Q) Practitioner • Sales and Marketing Manager • Sales Representative • Social Scientist • Supply Chain Practitioner	• Electric Vehicle Station Manager • Green Hydrogen Marketing Practitioner

• Radiation Protection Expert • Regulatory Affairs Officer • Renewable Energy Specialist • Research and Development Manager • Research Consultant • Risk / Planning / Review / Analyst		
Energy efficiency: • Air-conditioning and Refrigeration Mechanic • Auditor • Boiler and Pipe Insulation Worker • Boilermaker • Business Consultant • Campaign Specialist • Climate Change Analyst • Climate Change Scientist • College Lecturer • Control & Instrumentation Engineer • Corporate Communication Manager • Diesel Mechanic • Digital Media Designer • Digital Media Specialist • Electric Power Generation Engineer • Electric Power Plant Operator • Electrical Educator • Electrical Engineer • Electrical Engineering Technician • Electrical Engineering Technologist • Electrical Foreman • Electrician • Electronic Engineering Technician • Energy Efficiency Manager • Energy Efficiency Specialist • Energy Efficiency Technician • Energy Engineer • Energy Engineering Technologist	Energy efficiency: Carry over of occupations listed in the short term	Energy efficiency: Carry over of occupations listed in the short term

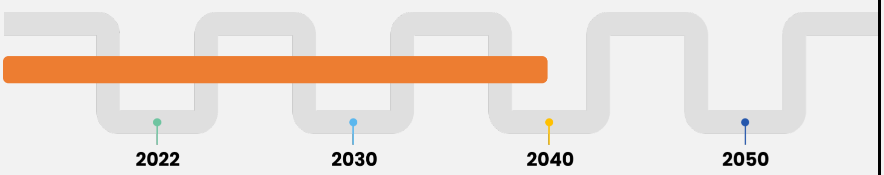
• Energy Specialist • Engineering Educator • Engineering Maintenance Manager • Engineering Manager • Engineering Teacher • Environmental Manager • Environmental Scientist • Facilities Manager • Finance Director • Finance Manager • Financial Business Analyst • Fossil Power Plant Process Controller • Fossil Power Plant Process Operator • Fossil Power Plant Process Technician • Graphic Artist • Instrument Mechanician (Industrial Instrumentation & Process Control) • Insulating Contractor • Insulation Installer • Internal auditor • Machine Operator • Maintenance Planner • Maintenance Technologist • Mechanic • Mechanical Engineer • Mechanical Engineering Technologist • Metre Technician • Millwright • Operations Manager (Production) • Power Station Attendant • Procurement Administrator / Coordinator / Officer • Procurement Manager • Programme or Project Manager • Quality Assurance / Systems Auditor • Safety, Health, Environment and Quality (SHE&Q) Practitioner • TVET Educator • University Lecturer		

<table>
<tr><th colspan="3">Trend: Climate Change: Resilient and adaptable energy systems</th></tr>
<tr><td>Time horizon</td><td colspan="2"></td></tr>
<tr><td>Impact on the world of work</td><td colspan="2">
Climate change and environmental degradation pose economic growth and employment challenges, and risks will become more significant in the medium- to long-term. However, if appropriately managed and mitigations are put in place, climate change and the associated impacts can create new work opportunities, and secure current jobs (EESI, 2021; ILO, 2023).
Occupations in the energy sector will be required to develop and implement disaster risk and adaptation strategies and interventions, including integration into current plans. This includes review of current infrastructure, risk management, strategic thinking and problem solving, forecasting and modelling, and actuarial analysis at all levels of government.
Current and future infrastructure plans (including smart cities, urban design and spatial planning) will require individuals to adequately review plans to ensure infrastructure is resilient and can withstand climatic shocks e.g. droughts and floods.
To ensure adequate buy-in to mitigation strategies and interventions, personnel and stakeholder awareness will be critical, and requires education practitioners to undertake this role.
In addition to the above a core component of resilience will be a shift towards more renewables and adopting energy efficiency practices (see the climate change: Achieving net zero carbon emissions by 2050 trend above).
</td></tr>
<tr><td>Minor occupation groups</td><td colspan="2">
Managing Directors and Chief Executives
Physical and Earth Science Professionals
Mathematicians, Actuaries and Statisticians
Life Science Professionals
Engineering Professionals
Architects, Planners, Surveyors and Designers
University and Higher Education Teachers
Finance Professionals
</td></tr>
<tr><td colspan="3">Types of priority occupations required for the transition
Also see the climate change: Achieving net zero carbon emissions by 2050 trend above, and for modelling and analysis see the automation and digitalisation trend below).</td></tr>
<tr><td>2023 - 2030
(Short term)
Actuary
Campaign Organiser
Climate Change Analyst
Climate Change Scientist
Climate Change Specialist
</td><td>2031 - 2040
(Medium term)

Carry over of occupations listed in the short term, plus and increased focus on the following:
Communication Coordinator
</td><td>2041 - 2050
(Long term)

Carry over of occupations listed in the short and medium term, plus and increased focus on the following:
Civil Engineer
</td></tr>
</table>

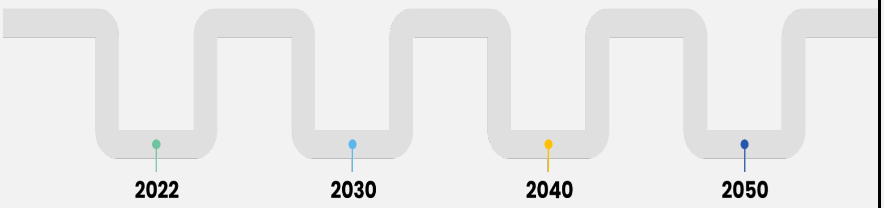
• Climate Finance Specialist • Energy Economist • Energy Specialist • Environmental Educator • Environmental Scientist • Environmentalist • Finance and Insurance Consultant • Investment Analyst • Policy Advisor • Policy and Planning Manager • Policy Consultant / Officer / Planner • Policy Development Manager • Public Policy Manager • Remote Sensing Technicians • Resource Economist • Risk / Planning / Review / Analyst • Statistical Modeller • Trade Union Official • Urban and Regional Planner	• Engineering Educator • Environmental Engineer • Financial Markets Practitioner • Grid Integration Manager • Grid Integration Specialist • Remuneration and Benefits Specialist • Safety, Health, Environment and Quality (SHE&Q) Practitioner • Social Scientist • Supply Chain Practitioner • Tax Professional	• Civil Engineering Technician • Civil Engineering Technologist • Construction Project Director • Construction Site Manager • Corporate Services Manager • Environmental Manager • Work Site Engineering Technician

Trend: Shifting towards sector coupling	
Time horizon	
Impact on the world of work	• The electrification of the economy will have a significant impact on jobs, as new technologies, innovative industrial processes and rules are rolled out and energy-consuming sectors e.g., buildings, transport and industry become interconnected with the energy sector. Initially the impact will be felt in the electricity sector, due to the expansion of renewables, but will shift into the other sectors as renewables and clean energy interventions are adopted by energy consuming sectors (Appunn, 2018; IRENA, 2022a). Also see the climate change: Achieving net zero carbon emissions by 2050 trend above (renewable energy and clean energy [electric vehicles, green hydrogen]) above, and automation and digitalisation trend below.
Minor occupation groups	• Legislators and Senior Officials • Manufacturing, Mining, Construction and Distribution Managers • Professional Services Managers • Engineering Professionals • Electrotechnology Engineers

<table>
<tr><td></td><td colspan="2">Finance Professionals
Sales, Marketing and Development Managers</td></tr>
<tr><td colspan="3">Types of priority occupations required for the transition.
Also see the climate change: Achieving net zero carbon emissions by 2050 trend above (renewable energy and clean energy [electric vehicles, green hydrogen]) above, and automation and digitalisation trend below.</td></tr>
<tr><td>2023 - 2030
(Short term)
Renewable Energy Specialist
Renewable Energy Specialist
Research and Development Manager
Research Consultant
Risk / Planning / Review / Analyst
Statistical Modeller
Proposal Engineer
Public Policy Manager
Regulatory Affairs Officer
Policy Advisor
Policy and Planning Manager
Policy Consultant / Officer / Planner
Policy Development Manager
Mineral Economist
Green Economy Specialist
Financial Business Analyst
Financial Markets Investment Advisor
Energy Economist
Energy Specialist
Energy Storage Advisor
Electric Vehicle Specialist
Electrical Design Engineer
Cost Modelling / Industry Analyst
Circular Economy Specialist
Business Consultant</td><td>2031 - 2040
(Medium term)

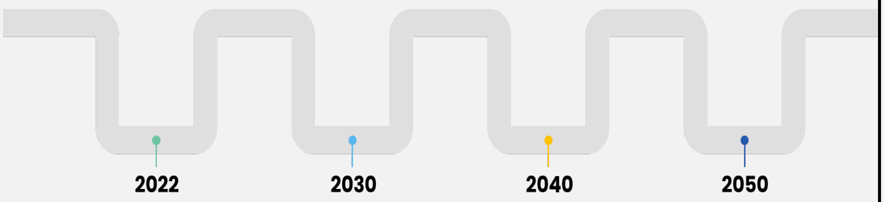
Carry over of occupations listed in the short term, plus and increased focus on the following:
Supply Chain Practitioner
Procurement Administrator / Coordinator / Officer
Procurement Manager
Programme or Project Manager
Power Distribution Manager
Power Systems Engineer
Process Design Engineer
Process Design Technician
Mining Manager
Fuel Cell Engineer
Fuel Cell Technician
Financial Markets Practitioner
Energy Storage Engineer
Energy Storage Technician
Engineering Educator
Environmental Engineer
Electrochemist
Compliance Officer
Construction Manager
Contract Manager
Contracts Lawyer
Contracts Officer
Business Development Manager</td><td>2041 - 2050
(Long term)

Carry over of occupations listed in the short and medium term, plus and increased focus on the following:
Operations Manager (Production)
Logistics Manager
Facilities Manager
Electronic Engineering Technician
Electrical Engineer
Director (Enterprise / Organisation)
Corporate General Manager</td></tr>
</table>

<table>
<tr><th colspan="3">Trend: Evolving energy markets</th></tr>
<tr><td>Time horizon</td><td colspan="2">
</td></tr>
<tr><td>Impact on the world of work</td><td colspan="2">An expansion in renewables will require a shift in the market to one that is more decentralised and privatisation of activities (DMRE, 2022a). With a shift towards more privatisation and decentralisation, more responsibility will fall on local governments to procure, negotiate and set tariffs, trade and manage the electricity generated within their jurisdictions. Electricity may be generated by the municipalities themselves, Independent Power Producers (IPPs) or cooperatives.
Support will be required to build local government, IPPs and cooperative capabilities to generate, procure and deliver electricity. In the case of local governments, this will require adequate leadership, governance, strategic direction, management and coordination of projects and technical knowledge and skills (SA Government, 2022).
Cooperatives provide an opportunity to create local employment, especially in rural areas, through not only electricity generation, but also through service provision. Therefore, awareness of such opportunities needs to be made known, and they require the collective capabilities to respond to the localised demand (ILO, 2013).</td></tr>
<tr><td>Minor occupation groups</td><td colspan="2">Legislators and Senior Officials
Managing Directors and Chief Executives
Business Services and Administration Managers
Sales, Marketing and Development Managers
Retail and Wholesale Trade Managers
Engineering Professionals
Electrotechnology Engineers
Vocational Education Teachers
Finance Professionals
Administration Professionals
Sales, Marketing and Public Relations Professionals
Database and Network Professionals
Legal Professionals
Sales and Purchasing Agents and Brokers
Regulatory Government Associate Professionals
Client Information Workers
Numerical Clerks</td></tr>
<tr><td colspan="3">Types of priority occupations required for the transition
Also see the deteriorating energy security trend above.</td></tr>
<tr><td>2023 - 2030
(Short term)
College Teacher</td><td>2031 - 2040
(Medium term)</td><td>2041 - 2050
(Long term)</td></tr>
</table>

• Compliance Officer • Construction Manager • Contract Manager • Contracts Lawyer • Contracts Officer • Corporate Services Manager • Cost Engineer • Cost Modelling / Industry Analyst • Economist • Electric Power Generation Engineer • Electric Substation Operations Manager • Electrical Design Engineer • Electrical Educator • Electrical Engineer • Electrical Inspector Construction • Energy Economist • Energy Engineer • Energy Specialist • Engineering Educator • Finance Director • Financial Markets Investment Advisor • General Manager Public Service • Grid Integration Manager • Human Resource Manager • Independent Power Producer (IPP) Specialist • Investment Advisor • Investment Analyst • Lawyer • Legal Advisor • Local Economic Development Manager • Municipal Manager • Planning & Development Manager • Policy Advisor • Policy and Planning Manager • Policy Consultant / Officer / Planner • Policy Development Manager • Power Distribution Engineer	Carry over of occupations listed in the short term, plus and increased focus on the following: • Billing Administrator / Representative / Officer • Billing and Settlement Plan (BSP) Manager • Debtors Manager • Electrical Engineering Technician • Electrical Engineering Technologist • Electrician • Electronic Engineering Technician • Energy Broker • Energy Engineering Technologist • Energy Storage Specialist • Environmental Educator • Financial Market Dealer • Financial Markets Practitioner • General Accountant • Internal auditor • Maintenance Planner • Maintenance Technologist • Marketing Practitioner • Municipal Finance Manager • Operations Manager (Production) • Power Distribution Manager • Power Distribution Technician • Power Generation Operations Manager • Procurement Administrator / Coordinator / Officer • Procurement Manager • Programme Evaluator • Property Portfolio and Asset Manager • Quality Assurance / Systems Auditor • Sales and Marketing Manager • Sales Representative • TVET Educator	Carry over of occupations listed in the short and medium term.

• Power Distribution Planner • Power Systems Engineer • Power Transmission Engineer • Pricing Clerk / Analyst / Estimator • Process Design Engineer • Process Operator • Programme and Project Manager • Public Policy Manager • Regulatory Affairs Officer • Research and Evaluation Analyst • Security Advisor • Security Guard • Shutdown Coordinator / Planner • Small Business Consultant / Mentor • Social Scientist • Statistical Modeller • Supply Chain Practitioner		

Trend: Automation and digitalisation	
Time Horizon	
Impact on the world of work	• Automation, digitalisation and technological changes will significantly impact and disrupt jobs through the need for new work systems, processes and procedures. This will result in the creation of new jobs, job displacement or the need to adapt current jobs to adopt digital and automation technologies. This in turn will require extensive and continuous upskilling, reskilling and retraining (Chui, Lund and Gumbel, 2018; EWSETA, 2021; IEA, 2017; Torkington, 2023). ○ Examples of job displacement include those involved in routine, predictable and repetitive tasks, unsafe work environments or where automation replaces humans e.g. truck drivers replaced by fully autonomous cars and trucks (Careers in Energy, 2023; IEA, 2017). • Policy developers in the energy and coupled sectors should participate in broader government and industry discourse to prepare and manage the sectors' for a digital transition (IEA, 2017). • The implementation of a digital infrastructure will require specialist ICT skills (high levels of specific digital skills are needed), such as coding and cybersecurity, while across the sector all employees

<table>
<tr><td></td><td colspan="2">will require generic ICT skills for more basic or broad tasks and to operate digital and automation technologies and machinery e.g. use of automation and digital devices and sensors to diagnose issues and optimise electricity generation operations (AISC, 2022; AIS, 2019; IEA, 2017).
● It is imperative that labour market, demographic, and skills supply and demand assessments are undertaken within the energy and related sectors to temper job loss fears, and to identify sector specific opportunities. Otherwise job losses and skills gaps will begin to arise as the evolution of technology outpaces the number of individuals trained, this could be exacerbated by education curricula being dated, and youth (who do not have access to computers) not developing digital skills (DHET, 2022; IEA, 2017).
● Skills supply will also be impacted by an increase in digitalisation, with e-learning becoming more prominent. As such, the sector and/or associated education and training providers will need to invest in upskilling educators and digital infrastructure (EWSETA, 2021).</td></tr>
<tr><td>Minor occupation groups</td><td colspan="2">● Legislators and Senior Officials
● Managing Directors and Chief Executives
● Manufacturing, Mining, Construction and Distribution Managers
● Information and Communications Technology Service Managers
● Engineering Professionals
● Electrotechnology Engineers
● Architects, Planners, Surveyors and Designers
● University and Higher Education Teachers
● Vocational Education Teachers
● Software and Applications Developers and Analysts
● Database and Network Professionals
● Physical and Engineering Science Technicians
● Process Control Technicians
● Information and Communications Technology Operations and User Support Technicians
● Machinery Mechanics and Repairers
● Electrical Equipment Installers and Repairers
● Electronics and Telecommunications Installers and Repairers</td></tr>
<tr><td colspan="3">Types of priority occupations required for the transition</td></tr>
<tr><td>2023 - 2030
(Short term)
● Applications Programmers
● Back-End Developer
● Cloud Computing Specialist
● Computer Engineering Mechanic / Service Person
● Computer Network Professionals
● Computer-Aided (CAD) Designer</td><td>2031 - 2040
(Medium term)
Carry over of occupations listed in the short term, plus and increased focus on the following:
● Artificial Intelligence (AI) / Machine Learning Specialist
● Automation Engineer
● Automation Engineering Technician
● Blockchain Specialist</td><td>2041 - 2050
(Long term)
Carry over of occupations listed in the short term and medium term, plus new currently unknown specialisms.</td></tr>
</table>

• Control & Instrumentation Engineer • Data Centre Operator • Data Processing Manager • Data Scientist • Database Analyst • Database Architect • Database Designer and Administrator • Database Security Expert • Digital Execution Manager • Digital Media Specialist • E-commerce Specialist • Front-End Developer • Full Stack Engineer • Human Resource Manager • ICT Developer • ICT Educator • ICT Programmer • ICT Security Architect • ICT Security Specialist • ICT Systems Architect • Internet Developer • Legal Advisor • Machine Educator • Metre Technician • Policy Analyst • Policy and Planning Manager • Policy Consultant / Officer / Planner • Policy Development Manager • Public Policy Manager • Social Media Specialist • Skills Development Strategist • Software Engineer • Software Technician • Technical ICT Support Services Manager • Technopreneur • Web Editor / Designer	• Drone Operator • Electrical Engineer • Electrical Engineering Technician • Electrical Engineering Technologist • Grid Integration Manager • Instrument Mechanician (Industrial Instrumentation & Process Control) • Power Distribution Engineer • Power Systems Engineer • Power Transmission Engineer • Product Manager • Programme or Project Manager • Robotics and Production Automation Engineer • Robotics and Production Automation Technician • Sales Representative	

Appendix 2: Detailed list of identified energy system-related courses offered by South Africa's post-school education and training system

It should be noted that while every effort was made to ensure the accuracy, relevance and up-to-date nature of the courses listed the authors acknowledge that this list is not all-inclusive.

Figure 19:List of energy system-related courses

Course title / topic	Course type title
Traditional universities	
Mpumalanga University	
Environmental Science	BSc, MSc
Nelson Mandela University	
Chemical Process Technology	Dip
Electrical Engineering	BSc
Environmental Management	BSc
Geography & Environmental Science	BA / BSc
Mechatronic Engineering	HCert
Mechatronics	BEng
Photovoltaic Technology & Systems	Short course
Renewable Energy Artisan	HCert
Renewable Energy Finance & Policies	Short course
Renewable Energy Technology	Short course
Wind Energy Technology & Systems	Short course
North West University	
Environmental Science	BSc
Biochemistry & Microbiology	MSc, PhD
Chemical Engineering	PhD
Education: Science & Technology	Med, PhD
Electrical Engineering	BSc, MEng, PhD
Electromechanical Engineering	BSc
Environmental Management	Short course
Geography	MSc, PhD
Geography & Environmental Science	BSc, MSc, PhD
Mechanical Engineering	Meng, PhD
Mechatronic Engineering	BSc
Nuclear Science & Technology	PG Dip, MSc, PhD
Systems Engineering	Short course
Rhodes University	
Education: Science & Technology	PGCE, PG Dip, BEd Hons, MEd, PhD
Biochemistry & Microbiology	BSc, Hons
Biotechnology	BSc Hons, MSc, PhD
Chemistry	BSc, Hons, MSc
Environmental Law	LLM
Environmental Science	BA / BSc, Hons, MSc, PhD
Geography	BA / BSc, Hons, MA / MSc, PhD
Geology	BSc, Hons, MSc, PhD

Physics & Electronics	BSc, Hons, MSc, PhD
Sefako Makgatho Health & Sciences University	
Biotechnology	BSc, Hons, MSc, PhD
Chemistry	BSc Hons, MSc, PhD
Environmental Management & Toxicology	BSc
Stellenbosch University	
Biochemistry	BSc Hons, MSc, PhD
Chemical Engineering	PGDip, BEng, MEng
Chemistry	BSc, Hons, MSc, PhD
Earth Science	BSc, Hons, MSc, PhD
Electrical & Electronic Engineering	BEng, MEng, PhD
Engineering	PhD
Environment Management	PGDip
Geography & Environmental Studies	MSc, PhD
GeoInformatics	BSc, Hons, MSc, PhD
Integrated Demand Side Technologies	Short course
Mechanical Engineering	PGDip, BEng, MEng
Molecular Biology & Biotechnology	BSc
Physics	BSc, MSc, PhD
Power Systems & Operation	PGDip, MEng
Smart Grid Communications	Short course
Smart Grid Technology	Short course, PGDip, MEng
Sustainable Development	Dip, PGDip, MPhil
Sustainable Development Law	LLM
Transport & Logistics	PGDip
University of Cape Town	
Atmospheric Science	BSc Hons
Biochemistry	BSc
Bioprocess Engineering	MSc, PhD
Catalytic Process Engineering	MSc, PhD
Chemical Engineering	BSc
Chemical Engineering Education	PhD
Chemistry	BSc, MSc
Climate Adaptation	Short course
Climate Change & Sustainable Development	MSc / MPhil
Climate Change Mitigation in Developing Countries	Short course
Electrical Engineering	BSc, MSc, PhD
Energy Efficiency & Sustainability	Short course
Engineering Education	PhD
Environment, Society & Sustainability	MSc / MPhil
Environmental & Geographical Science	BA / BSocSc / BSc, Hons, MA / MSc, PhD
Environmental Engineering	PhD
Environmental Humanities	MPhil
Environmental Law	PG Dip, LLM
Law of Mineral & Petroleum Extraction & Use	LLM
Marine & Environmental Law	PG Dip, LLM
Mechanical & Mechatronic Engineering	BSc

Mechanical Engineering	BSc
Mechatronics	BSc
Nuclear Power	BSc Hons
Ocean & Atmosphere Science	BSc, MSc
Power Plant Engineering	Dip
Tertiary Chemistry Education	MSc
University of the Free State	
Climate Sciences	BSc
Chemistry & Biochemistry	BSc
Geography & Environmental Science	BSc
Geography & Life Sciences	BSc
Science & Technology Education	Med, PhD
University of Johannesburg	
Science Education (STEM)	BEd Hons
Analytical Chemistry	Dip
Applied Renewable Energy	Short course
Applied Solar Energy	Short course
Biochemistry	MSc, PhD
Biochemistry & Botany	BSc
Biochemistry & Chemistry	BSc
Biotechnology	MSc
Chemical Engineering	BEng, Hons
Chemical Engineering Technology	Meng, PhD
Chemistry	BSc Hons, MSc, PhD
Electrical & Electronic Engineering	BEng, MEng, PhD
Electrical Engineering	Dip, BEngTech, Hons
Energy Studies	BSc Hons, MSc, PhD
Energy Studies	
Engineering Management	Meng / MSc, PhD
Geography & Environmental Management	BSc
Green Building Applications	Short course
Green Building Legislation	Short course
Heat & Mass Transfer	Short course
Industrial Engineering	BEngTech, Hons, Meng, PhD
Mathematics, Science, ICT & Technical Education	MEd
Mechanical Engineering	BEngTech, Hons, Meng, PhD
Micro & Nanoelectronics Engineering	MEng
Mine Surveying	BEngTech, Hons
Mining Engineering	BEngTech, Hons
Science Education	MEd
Science Education (STEM)	BEd Hons, MEd
Social Impact Assessment (SIA)	Short course, MA
Sustainable & Smart Cities & Regions	Masters
Sustainable Energy	MEng
Sustainable Mining	MEng
Technology Education (STEM)	BEd Hons
Transport Management	Adv Dip

Urban Sustainability Management	Short course
University of KwaZulu Natal	
Applied Chemistry	BSc
Biochemistry	BSc, Hons, MSc, PhD
Bioresources Systems	MSc, PhD
Bioresources Systems	PhD
Chemical Engineering	BScEng, MSc, PhD
Chemical Technology	MSc, PhD
Chemistry	BSc Hons, MSc, PhD
Chemistry & Chemical Technology	BSc
Community development	BA Hons, MA, PhD
Development Studies	BA, Hons, MA, PhD
Electrical Engineering	BScEng, MSc, PhD
Electronic Engineering	BScEng, MSc, PhD
Engineering Access	BSc
Environmental & Earth Science	BSc
Environmental Engineering	MSc, PhD
Environmental Law	LLM
Environmental Science	BSc, Hons, MSc, PhD
Geography	BSc, MSc, PhD
Geography & Environmental Management	BSocSc
Geological Science	BSc
Geology	BSc Hons
Hydrology	BSc, Hons, MSc, PhD
Industrial & Applied Biotechnology	BSc
Land Surveying	BSc, MSc
Life & Earth Sciences	BSc
Mechanical Engineering	BScEng, MSc, PhD
Mechatronics	MSc
Physics	BSc, Hons, MSc, PhD
Quantity Surveying	MSc
Remote Sensing & Hydrology	Short Course
Science Education	BEd Hons, Med, PhD
Urban & Regional Planning	BA Hons, MA, PhD
Waste & Resources Management	MSc
University of Limpopo	
Chemistry	BSc Hons
Chemistry	MSc, PhD
Environmental & Resource Studies	BSc
Geology	BSc
Geology	BSc Hons
Geology	MSc, PhD
Mining Geology	BSc Hons
Physical Science	BSc
Science & Technology Education	BEd
Science Education	BEd Hons, Med, PhD
Technology Education	BEd Hons, Med, PhD

University of Pretoria	
Applied Science Chemical Technology	BSc Hons, MSc
Applied Science Electrical, Electronic & Computer Engineering	MSc
Applied Science Environmental Technology	BSc Hons, MSc
Applied Science Geotechnics	MSc
Applied Science Mechanics	BSc Hons, MSc
Applied Science Mining	BSc Hons, MSc
Biochemistry	BSc, Hons, MSc, PhD
Bioengineering	MEng
Biotechnology	BSc, Hons, MSc, PhD
Chemical Engineering	BEng, Hons, MEng, PhD
Chemical Technology	PhD
Chemistry	BSc, Hons, MSc, PhD
Coal Preparation	Short course
Electrical Engineering	BEng, Hons, MEng, PhD
Electronic Engineering	BEng, MEng, PhD
Electronics	PhD
Energy Management	Short Course
Energy Optimisation Tools	Short Course
Energy Policy & Electricity Market Operation	Short Course
Engineering & Environmental Geology	BSc, MSc, PhD
Engineering & Environmental Geology	BSc Hons
Engineering & Technology Management	BEng Hons
Engineering & Technology Management	BSc Hons
Engineering Management	MSc
Environmental Engineering	BEng Hons, MEng
Environmental Law	Short course, LLM / MPhil
Environmental Management & Regulation	Short course
Generator Technology	Short course
Geography	MSc, PhD
Geography & Environmental Science	BSc / BSocSc, Hons
Geoinformatics	BSc, Hons, MSc, PhD
Geological Site Investigation Techniques for Engineers	Short course
Geology	BSc, Hons, MSc, PhD
Geotechnical Engineering	BEng Hons, MEng
Geotechnical Engineering Practitioner	Short course
Hydrogen Fuel Cell Systems	Short Course
Land Rehabilitation: Reclamation & Restoration	Short course
Life Science Education	BEd Hons
Mechanical Engineering	BEng, Hons, MEng, PhD
Mechanics	PhD
Metallurgical Engineering	BEng
Meteorology	BSc, Hons, MSc
Microelectronic Engineering	MEng
Mine Closure & Land Rehabilitation	Short course
Mining Engineering	BEng, Hons, Meng, PhD
Physics	BSc Hons, MSc

Power System Protection in Smart Grid Environments	Short course
Practical Electrical Wiring	Short course
Programme in Asset & Maintenance Management	Short course
Programme in Blasting Engineering	Short course
Programme in Engineering Management	Short course
Programme in Environmental Management	Short course
Programme in Maintenance Management	Short course
Project Management for the Mining Industry	Short course
Recent Advances in Environmental Law	Short course
Renewable Energy: Distributed Generation	Short course
Science & Mathematics Education	PhD
Science Education	MSc
Sustainable Management	Short course
Technical & Operational Surface Mining Excellence	Short course
Technological Entrepreneurship & Innovation	Short course
Technology & Innovation Management	MEng
Technology Education	BEd Hons
Transport Engineering	MEng
UNISA	
Applied Mathematics & Physics	BSc
Chemistry & Applied Mathematics	BSc
Chemistry	BSc Hons, MSc, PhD
Chemistry & Physics	BSc
Chemical Engineering	Dip, BTech Hons
Chemistry Education	MEd, PhD
Engineering	MEng, PhD
Engineering Technology in Civil Engineering	Adv Dip
Electronic Engineering	Dip, BTech, BTech Hons
Electrical Engineering in Telecommunications	Adv Dip
Environmental Management	MSc, PhD
Environmental Science	MSc, PhD
Environmental Law & Environmental Management	Short course
Environmental Law & Liabilities for the Regulated Community	Short course
Geography	MSc, PhD
Human & Environmental Issues	
Intermediate Phase Natural Science & Technology Education	Adv Dip
Life Science Education	MEd, PhD
Mechanical Engineering	Dip, Adv Dip
Mining Engineering	Dip, Adv Dip
Natural Science Education	MEd
Physics	MSc, PhD
Physics Education	MEd, PhD
Programme for Environmental Educators	Short course
Science Education	MEd, PhD
Senior Phase Natural Science Education	Adv Dip
Technology Education	MEd, PhD
University of Venda	

Agricultural & Rural Engineering	BSc
Chemistry	BSc, Hons, MSc, PhD
Walter Sisulu University	
Analytical Chemistry	Dip
Electrical Engineering	Dip, Adv Dip
Environmental Studies	BSc, Hons
Mechanical Engineering	Dip, Adv Dip
University of the Western Cape	
Accelerator & Nuclear Physics	BSc Hons
Analytical chemistry	BSc
Applied Chemistry	BSc
Applied Geology	BSc, MSc, PhD
Biotechnology	BSc, Hons, MSc, PhD
Chemical Science	BSc, Hons, MSc
Chemistry	PhD
Environmental chemistry	BSc
Environmental Law	LLM, PhD
Geography	BA, Hons, MA, PhD
Geography & Environmental Studies	BA, Hons, MA, PhD
Inorganic Chemistry	BSc
Nanochemistry	MSc
Nanophysics	MSc
Organic Chemistry	BSc
Physical chemistry	BSc
Physics	PhD
Physics Education	PhD
Science Education	BEd Hons, MEd, PhD
University of the Witwatersrand	
Biochemistry	BSc, Hons, MSc
Biotechnology	BSc, Hons
Chemical Engineering	PG Dip, BSc, MSc, PhD
Chemistry	BSc, Hons, MSc, PhD
Electrical Engineering	PG Dip, BSc, MEng, PhD
Environmental & Geographical Science	BA / BSocSc / BSc, Hons, MA / MSc, PhD
Environmental Engineering	MEng, PhD
Industrial Engineering	BSc, MEng, PhD
Introduction to Offshore Oil & Gas Platforms/Pipelines	Short course
Introduction to Oil & Gas Production	Short course
Management in the Field of Energy Leadership	BSc
Mechanical Engineering	PG Dip, BSc, MEng, PhD
Mining Engineering	BSc, MSc, PhD
Nanotechnology of Oil & Gas	Short course
Physics	BSc, MSc, PhD
Systems Engineering	BSc, MSc
Universities of Technology	
Cape Peninsula University of Technology	
Analytical Chemistry	Dip Adv Dip, MSc, PhD

Biotechnology	Dip
Chemical Engineering	Dip, Adv Dip, BEngTech, MEng, DEng
Electrical (Power Systems)	Dip
Electrical Engineering	Dip, BTech Hons, MEng, DEng
Electrical Engineering (Smart Grid)	MEng
Energy	MEng
Engineering Management	PG Dip, MEng
Environmental Management	Dip, Adv Dip
Facility Management	Adv Dip
Industrial Design	Adv Dip
Industrial Engineering	Dip, Adv Dip
Mechanical Engineering	Dip
Mechanical Engineering	MEng, DEng
Mechanical Engineering (Mechatronics)	Dip, Adv Dip
Mechanical Engineering (Renewable Energy)	Adv Dip
Solar PV GreenCard	Short course
Solar PV Installer Course	Short course
Wind Energy for Engineers & Technicians	Short course
Wind Energy for Generalists	Short course
Wind Turbine Service Technicians	Short course
Cape Peninsula University of Technology	
Design Technology	Adv Dip
Electrical Engineering	Dip, BEng, MEng, DEng
Engineering Technology	Dip, BTech
Engineering Technology	
Logistics & Transportation Management	Adv Dip
Mathematics for Engineering Technology	HCert
Mechanical Engineering	Dip, BEng, BEng Hons, MEng, DEng
Renewable Energy Technologies	HCert
Technology Education	BEd
Durban University of Technology	
Biotechnology	Adv Dip, BAppSc, Hons, MAppSc, PhD
Chemical Engineering	MEng
Chemical Engineering	DEng
Electric Power Engineering	BEngTech, Hons
Electrical (Heavy Current)	BTech
Electrical Engineering	MEng, DEng
Electronic Engineering	BEngTech, MEng, DEng
Engineering Technology	BEngTech
Planning Large Scale Grid-Connected Photovoltaic	Short course
Power Engineering	BEngTech Hons
Power Engineering (Heavy Current)	BEngTech
Small Scale Grid-Connected Photovoltaic	Short course
Solar Photovoltaic Fundamentals	Short course
Mangosuthu University of Technology	
Analytical Chemistry	Dip, Adv Dip
Chemical Engineering	Dip, Adv Dip

Community extension	Dip
Electrical Engineering	Dip
Mechanical Engineering	Dip
Surveying	Dip
Tshwane University of Technology	
Analytical Chemistry	Dip
Biotechnology	Adv Dip, PG Dip, MAppSci, PhD
Chemical Engineering	Adv Dip, PG Dip, MAppSci, PhD
Chemistry	Adv Dip, PG Dip, MAppSci, PhD
Electronic Engineering	HCert, Dip, Adv Dip, PG Dip, BTech, Hons, MEng, PhD
Energy Efficiency	MEng
Environmental Science	Dip, Adv Dip
Geography	Dip,
Industrial Engineering	Dip, Adv Dip, PG Dip, BTech, Hons, MEng, PhD
Mechanical Engineering	HCert, Dip, Adv Dip, PG Dip, BTech, Hons, MEng, PhD
Metallurgical Engineering	Dip,
Systems Engineering	Dip, PG Dip
Vaal University of Technology	
Analytical Chemistry	Dip, Adv Dip, PG Dip, MAppSci, PhD
Biotechnology	Dip, Adv Dip, PG Dip, MAppSci, PhD
Chemical Engineering	Dip, Adv Dip, PG Dip, MEng, DEng
Electronic Engineering	Dip, Adv Dip, PG Dip, MEng, DEng
Energy Efficiency	MEng
Environmental Science	Dip
Industrial Engineering	Dip, Adv Dip, PG Dip, MEng, DEng
Mechanical Engineering	Dip, Adv Dip, PG Dip, MEng, DEng
Power Engineering	Dip, Adv Dip, PG Dip, MEng, DEng
Process Control Engineering	Dip, Adv Dip, PG Dip, MEng, DEng
Private universities and colleges	
Green Solar Academy	
Financing of PV Systems	Short course
Green PV Designer Exam	Short course
Green PV Installer Exam	Short course
Principles of PV Systems	Short course
PV GreenCard Assessment	Short course
PV Mounter	Short course
PV Off-grid Technician	Short course
PV*Sol Design School	Short course
SAPVIA PV Assessment	Short course
Solar 101	Short course
Solar Power Designer for Commercial PV Systems	Short course
Solar PV Installation	Short course
MANCOSA	
4IR & Automation	Short course
Introduction to Robotics & Programming	Short course
Monash University	

Civil Engineering	BEng
Electrical & Electronic Engineering	BEng
Mechanical Engineering	BEng
Nepoworx Solar Academy	
PV GreenCard	Short course
Powerpro	
PV GreenCard	Short course
PQRS	
Solar PV Design & Install (Beginner)	Short course
Solar PV Design & Install (Intermediate)	Short course
Solar PV Products & PV Systems Sales	Short course
Qualitas Career Academy	
Electrical Engineering	Certificate
Electrician	Certificate
Sintech	
Solar Design & Installation	Short course
Solar Training Centre	
SF Food & Energy (Agri-voltaic)	Short course
Solar Installers	Short course
SSEG Technical & Financial	Short course
SUNCybernetics	
PV GreenCard	Short course
Terra Firma Academy	
Energy Management Fundamentals	Short course
The Knowledge Academy	
Robotic Process Automation	Short course
Varsity College	
Civil Engineering	BEng
TVET colleges	
Boland TVET College	
Electrical Engineering	Diploma
Electrical Infrastructure Construction	Certificate
Engineering & Related Design	Certificate
Buffalo City TVET College	
Electrical	Artisan training
Electrical Engineering	Certificate
Electrical Infrastructure Construction	Certificate
Engineering & Related Design	Certificate
Mechanical Engineering	Certificate
Mechatronics	Certificate
Capricorn TVET College	
Chemical Engineering	Certificate
Electrical Engineering	Certificate
Electrical Infrastructure Construction	Certificate
Engineering & Related Design	Certificate
Mechanical Engineering	Certificate
Mechatronics	Certificate

Process Plant Operation	Certificate
Transport & Logistics	Certificate
Central Johannesburg TVET College	
Boilermaking	Diploma
Electrical Engineering (Heavy Current)	Diploma
Electrical Engineering (Light Current)	Diploma
Engineering & Related Design: Electrical	Certificate
Engineering & Related Design: Fitting & Turning	Certificate
Engineering & Related Design: Motor or Welding	Certificate
Mechanical Engineering	Diploma
Coastal TVET College	
Electrical Engineering	Diploma
Electrical Infrastructure Construction	Certificate
Electronics	Artisan training
Engineering & Related Design (Automotive/Fabrication/Fitter & Turner)	Certificate
Mechanical Engineering	Diploma
Welding / Boilermaking	Artisan training
College of Cape Town for TVET	
Electrical Engineering	Diploma
Electrical Infrastructure Construction	Certificate
Engineering & Related Design	Certificate
Engineering Studies	Diploma
Mechanical Engineering Studies	Certificate, Diploma
Transport & Logistics	Certificate
Eastcape Midlands TVET College	
Certificate of Competency (Government Ticket)	Certificate
Electrical	Artisan training
Electrical Infrastructure Construction	Certificate
Electrical Trade	Diploma
Electrical/Electronic Engineering	Diploma
Electronics (Light / Heavy Current)	Certificate
Engineering & Related Design	Certificate
Fitting & Machining	Diploma
Mechanical Engineering Studies	Diploma
Mechatronics	Certificate
Ehlanzeni TVET College	
Electrical Engineering	Diploma
Electrical Infrastructure Construction	Certificate
Mechanical Engineering	Diploma
Ekurhuleni East TVET College	
Basic Electrical	Certificate
Dual System Pilot Project: Electrical	Artisan training
Electrical Engineering	
Electrical Engineering (Light / Heavy Current)	Diploma
Electrical Infrastructure Construction	Certificate
Engineering & Related Design	Certificate

Mechanical Engineering	Diploma
Mechatronics	Certificate
Process Plant Operation	Certificate
Elangeni TVET College	
Electrical Engineering	Diploma
Electrical Infrastructure Construction	Certificate
Engineering & Related Design	Certificate
Mechanical Engineering	Diploma
Esayidi TVET College	
Electrical Engineering	Certificate
Electrical Engineering (Light / Heavy Current)	Diploma
Electrical Infrastructure	Diploma
Engineering & Related Design	Diploma
Mechanical Engineering	Diploma
Transport & Logistics	Diploma
False Bay TVET College	
Competency Based Modular Training	Artisan training
Electrical Engineering	Certificate
Electrical Infrastructure Construction	Certificate
Fitting &Turning	Certificate
Mechanical Fitting	Certificate
Programming & Robotics	Certificate
Trade Level Tests	Artisan training
Transport & Logistics	Certificate
Welding Application & Practices	Certificate
Flavius Mareka TVET College	
Chemical Engineering	Certificate
Electrical	Diploma
Electrical Engineering	Certificate
Electrical Infrastructure Construction	Certificate
Engineering & Related Design	Certificate
Engineering Studies	Certificate
Transport & Logistics Level	Certificate
Gert Sibande TVET College	
Chemical Engineering	Certificate
Electrical Engineering	Certificate
Electrical Infrastructure Construction	Certificate
Electrician	Artisan training
Engineering & Related Design	Certificate
Engineering Studies	Certificate
Mechanical Engineering	Certificate
Mechanical Fitter	Artisan training
Mechatronics	Certificate
Welder	Artisan training
Goldfields TVET College	
Electrical Engineering	Diploma
Electrical Infrastructure Construction	Certificate

Engineering & Related Design	Certificate
Mechatronics	Certificate
Ikhala TVET College	
Electrical Engineering	Diploma
Electrical Infrastructure Construction	Certificate
Engineering & Related Design	Certificate
Ingwe TVET College	
Electrical Engineering	Diploma
Electrical Infrastructure Construction	Diploma
Engineering & Related Design	Diploma
Mechanical Engineering	Diploma
King Hintsa TVET College	
Electrical Infrastructure Construction	Certificate
Engineering	Diploma
Engineering & Related Design	Certificate
King Sabata Dalindyebo TVET College	
Artisan Development Programme	Diploma
Electrical Engineering	Certificate
Electrical Infrastructure Construction	Certificate
Engineering & Related Design	Certificate
Mechanical Engineering	Diploma
Lephalale TVET College	
Electrical Engineering	Diploma
Electrical Infrastructure Construction	Certificate
Engineering Related & Design	Certificate
Mechanical Engineering	Diploma
Letaba TVET College	
Engineering Studies	Diploma
Electrical Infrastructure Construction	Certificate
Electrician	Artisan training
Engineering & Related Design	Certificate
Transport & Logistics	Certificate
Lovedale TVET College	
Electrical Engineering Studies	Artisan training
Electrical Infrastructure Construction	Certificate
Engineering	Certificate
Engineering & Related Design	Certificate
Welding	Artisan training
Majuba TVET College	
Boilermaker	Artisan training
Chemical Engineering	Diploma
Electrical Engineering	Diploma
Electrical Engineering (Light / Heavy Current)	Certificate
Electrical Infrastructure Construction	Certificate
Electrical Technician	Artisan training
Electrician	Artisan training
Electro-Mechanician	Artisan training

Engineering & Related Design	Certificate
Mechanical Engineering	Diploma
Mechanical Technician	Artisan training
Welder	Artisan training
Maluti TVET College	
Electrical Engineering	Diploma
Electrical Infrastructure Construction	Certificate
Engineering & Related Design	Certificate
Mechanical Engineering	Diploma
Mnambithi TVET College	
Electrical Engineering	Diploma
Electrical Infrastructure Construction	Certificate
Electrician	Artisan training
Mopani South TVET College	
Electrical Engineering	Diploma
Mechanical Engineering	Diploma
Motheo TVET College	
Electrical Studies	Certificate
Electrical Engineering (Light / Heavy Current)	Diploma
Electrical Infrastructure Construction	Certificate
Electrician	Artisan training
Engineering & Related Design	Certificate
Mechanical Engineering	Diploma
Transport & Logistics	Certificate
Mthashana TVET College	
Electrical Engineering	Diploma
Electrical Infrastructure Construction	Certificate
Engineering Studies	Diploma
Mechanical Engineering	Diploma
Nkangala TVET College	
Electrical Infrastructure Construction	Certificate
Electrical Engineering	Diploma
Engineering & Related Design Level	Certificate
Mechanical Engineering	Diploma
Northern Cape Rural TVET College	
Boilermaking	Artisan training
Electrical	Skills programme
Electrical Engineering	Diploma
Electrical Infrastructure Construction	Certificate
Mechanical Engineering	Diploma
Northlink TVET College	
Boilermaking	Artisan training
Electrical	Certificate
Electrical Engineering (Light / Heavy Current)	Diploma
Engineering & Related Design	Certificate
Mechanical Fitter & Turner	Diploma
Orbit TVET College	

Diesel Mechanic	Artisan training
Electrical	Diploma
Electrical Engineering	Learnership
Electrical Infrastructure Construction	Certificate
Electrician	Artisan training
Electronics	Learnership
Engineering & Related Design	Certificate
Fitting & Turning / Boilermaking	Diploma
Mechanical	Learnership
Port Elizabeth TVET College	
Dual System Pilot Programme (Plumbing & Electrical)	Artisan training
Electrical Engineering	Diploma
Electrical Infrastructure Construction	Certificate
Engineering & Related Design	Certificate
Mechanical Engineering	Diploma
Mechatronics	Certificate
Sekhukhune TVET College	
Electrical Engineering	Diploma
Electrical Infrastructure	Certificate
Engineering & Related Design	Certificate
Mechanical Engineering	Diploma
South Cape TVET College	
Boilermaking	Certificate
Electrical	Certificate
Electrical Infrastructure Construction	Certificate
Engineering & Related Design	Certificate
Fitting & Turning	Certificate
South West Gauteng TVET College	
Chemical Engineering	Diploma
Electrical Engineering	Diploma
Electrical Infrastructure Construction	Certificate
Electrician	Certificate
Electronics	Certificate
Engineering & Related Design	Certificate
Environmental Education, Training & Development Practice	Certificate
Environmental Practice	Certificate
Mechanical Engineering	Diploma
Welding Application & Practice	Certificate
Taletso TVET College	
Electrical Engineering	Diploma
Electrical Infrastructure Construction	Certificate
Engineering & Related Design	Certificate
Mechanical Engineering	Diploma
Thekwini TVET College	
Electrical	Diploma
Electrical Engineering	Diploma
Electrical Infrastructure Construction	Certificate

Engineering & Related Design	Certificate
Mechanical	Diploma
Tshwane North TVET College	
Electrical Engineering	Diploma
Electrical Infrastructure Construction	Certificate
Engineering & Related Design	Certificate
Mechanical Engineering	Diploma
Tshwane South TVET College	
Basic Engineering Hand Tool Theory & Skills	Short courses
Electrical (Light / Heavy Current)	Diploma
Electrical Infrastructure Construction	Certificate
Engineering & Related Design	Certificate
Engineering Machines	Short courses
Mechanical Engineering	Learnership
Mechanical: Fitting & Machining	Diploma
Mechanical: Fitting & Turning	Diploma
Mechatronics	Learnership
Umfolozi TVET College	
Electrician	Artisan training
Umgungundlovu TVET College	
Electrical (Heavy Current)	Diploma
Electrical Infrastructure Construction	Certificate
Engineering & Related Design	Certificate
Mechanical Engineering	Diploma
Mechatronics	Certificate
Technology & Computer Science Robotics	Certificate
Vhembe TVET College	
Chemical Engineering	Certificate
Electrical Infrastructure Construction	Certificate
Engineering & Related Design	Certificate
Mechanical Engineering	Certificate
Vuselela TVET College	
Boilermaker	Artisan training
Electrical Engineering	Certificate
Electrical Infrastructure Construction	Certificate
Electrician	Artisan training
Engineering & Related Design	Certificate
Mechanical Engineering	Certificate
Waterberg TVET College	
Electrical Infrastructure Construction	Certificate
Engineering & Related Design	Certificate
West Coast TVET College	
Electrical Infrastructure Construction	Certificate
Engineering & Related Design	Certificate
Western College for TVET	
Electrical Infrastructure Construction	Certificate
Engineering & Related Design	Certificate

Engineering Certificate of Competency	Certificate
Engineering Studies	Certificate
Installation Rules & Specialised Installation Rules (Wireman's Licence)	Certificate
Community education & training colleges	
Free State CET College	
Basic Electricity	Certificate
North West CET College	
Basic Mechanical	Certificate

Appendix 3: Student enrolment in various fields of study

Field of study	Total enrolment
Architecture and the built environment	
020200 : city/urban, community and regional planning	1 906
020300 : building/construction site management	5 011
020900 : quantity surveying	2 088
Business, economics and management studies	
040100 : business administration, management and operations	79 498
040200 : accounting and related services	91 281
040300 : business/corporate communications	333
040400 : economics	19 618
040500 : entrepreneurial and small business operations	3 707
040600 : finance and financial management services	19 639
040800 : human resource management and services	17 719
041000 : management sciences and quantitative methods	3 050
041100 : marketing	14 339
041400 : insurance	983
Communication, journalism and related studies	
050400 : public relations, advertising and applied communication	9 004
Computer and information sciences	
060100 : computer and information sciences	16 518
060200 : computer programming	6 231
060300 : data processing and information science	6 578
060500 : data entry/microcomputer applications	852
060700 : computer software and media applications	919
060800 : computer systems networking and telecommunications	942
Education	
070600 : teaching; leading and researching in schooling contexts (further education and training (fet) phase)	13 987
070700 : teaching, leading and researching in community and adult education and training contexts	717
070800 : teaching; leading and researching in technical and vocational education and training (tvet) contexts	675
070900 : teaching, leading and researching in higher education	776
Engineering	

Field of study	Total enrolment
080600 : chemical engineering	7 723
080700 : civil engineering	16 435
080800 : computer engineering	2 544
080900 : electrical, electronics and communications engineering	19 016
081000 : engineering mechanics	266
081100 : engineering physics	205
081200 : engineering science	15
081300 : environmental/environmental health engineering	62
081700 : mining and mineral engineering	1 951
081900 : nuclear engineering	126
082000 : ocean engineering	5
082100 : petroleum engineering	-
082200 : systems engineering	879
082600 : construction engineering	831
082800 : industrial engineering	5 090
082900 : manufacturing engineering	161
083000 : operations research	481
083100 : surveying engineering	1 379
Law	
120400 : private law	37 552
120500 : public law	6 651
120600 : formal law	2 222
Life sciences	
131100 : biotechnology	2 090
Physical sciences	
140300 : atmospheric sciences and meteorology	394
140400 : chemistry	10 427
140500 : geography and cartography	17 947
140600 : geology and earth sciences/geosciences	3 291
140700 : physics	5 328
Mathematics and statistics	
150300 : statistics	5 516
Public management and services	

Field of study	Total enrolment
190200 : community organisation and advocacy	137
190300 : public administration	23 230
190400 : public policy analysis	588
Social sciences	
200100 : anthropology	3 938
200600 : political science and government	12 813
200700 : sociology	11 227
200900 : development studies	3 261